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PARENTERAL FEEDING OF PROTEIN

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THE PLACE of parenteral protein feeding depends first of all on the importance of protein feeding itself and second on the availablity of adequate methods. The need for protein feeding has become emphasized only in the past decade or two. The old ideas that protein is not important and that there are large stores of dispensable body protein have been almost completely discarded. One may assume as proved the harmful effects of protein starvation even for short periods. These evils, to be sure, are slight in the beginning. Certainly a person who is well nourished may withstand deprivation of protein and even considerable loss of protein as such without serious difficulty; but this does not mean that protein losses are without effect. A basic principle in the treatment of disease is that all deficits be avoided. Protein is no exception. Indeed, there is much evidence to show that protein deprivation provokes greater physiologic impairment than is the case with vitamins. Deficits in protein as in other nutritional elements should be avoided or corrected as part of the general treatment of the patient.

When the patient has already become malnourished or lost a considerable amount of protein as such, further loss or deprivation of protein becomes more obviously harmful. The serious effects of protein deficiencies are now realized; they are associated with many complications and even contribute in part to a fatal outcome. Regardless, therefore, of whether the patient is well nourished to start with or is already deficient when he comes under one's care, one must accept as necessary the need for maintaining protein intake in order to prevent as much as possible further protein depletion and, if possible, to correct whatever protein depletion is already present.

There are at least two general conditions in which parenteral administration of protein is indicated. The first is fairly well know—intravenous administration of hemoglobin and plasma protein as whole blood

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or plasma transfusions in conditions in which the deficit is largely confined to these two elements. Such conditions involve no special metabolic problem, for the patient has lost hemoglobin or has lost plasma protein as such and it is simply a matter of replacing what has been lost. One might argue, of course, that such losses would normally be replaced by regeneration of the missing proteins from other tissue or the food the patient eats. This, indeed, is true. The only difficulty is the length of time that may be required. For example, a patient who loses a liter of blood will certainly regenerate the plasma protein portion within a week or the hemoglobin loss within six weeks, and if there is no urgency one might suppose that this would be adequate. However, this period of time is rather long and other difficulties may complicate the picture. Since it is so simple and easy to correct such deficits at once, why wait for the body to meet them eventually? It is thus common practice to use the parenteral route by giving the patient whole blood or plasma transfusions immediately. In certain instances, indeed, the indications for the transfusion are more compelling—when the loss has been so acute that circulatory impairment has ensued. In this case the use of whole blood or plasma transfusion may be dramatically life saving.

The use of the parenteral route for the administration of protein food presents an entirely different problem. Here the patient is unable to use his gastrointestinal tract either because of obstruction or peritonitis or because the stomach and intestines are unable adequately to ingest and digest protein food. As is well known, protein food normally becomes available to the body not as such, but in the form of amino acids or small combinations thereof, so-called peptides, which are formed by the digestion of whole protein food. After absorption into the portal stream they pass through the liver and are then distributed to the rest of the body, there to become fabricated into the individual proteins characteristic of the tissue involved.

REQUISITES FOR PARENTERAL FEEDING

If one is to use the parenteral channel it would seem a priori that this would be the most physiologic method. The accomplishment of this theoretic possibility depends on at least two prerequisites. First, it is necessary to obtain a mixture containing all of the essential amino acids in adequate amounts. It has long been known, of course, that no protein containing less than the minimal amount of essential amino acids can meet protein needs. A second requirement is that the mixture provoke no serious consequences when injected either subcutaneously or intravenously. One would not expect this to occur if one used pure crystalline amino acids. Unfortunately, up to the present time at least, mixtures of pure amino acids have not become commercially

available, so that the only preparations which may be used by the physician and surgeon are solutions of hydrolyzed protein which have been prepared with sufficient care to meet the basic requirements mentioned herein.[1]

Regarding the parenteral route for the administration of amino acids, the question is often asked as to its beneficial effects. The answer should be as clear as the answer to the question as to what are the beneficial effects of the administration of protein by mouth. The only question to be answered is this: Are the amino acids given parenterally actually used as protein food? The evidence on which an affirmative answer to this last statement is based is extensive and will be discussed briefly.

EFFICACY OF PROTEIN FOOD

One of the ways in which the efficacy of protein food may be demonstrated is its ability to maintain nitrogen balance when fed as the sole source of nitrogenous nourishment. Thus, if a mixture of amino acids is given parenterally as the sole source of nitrogen and leads to nitrogen balance, i. e., provokes a loss of nitrogen equal to or less than it contains, one assumes that the material is used, in part at least, for the synthesis of body tissue protein. In a typical case, a patient, unable to take food by mouth, is given the ordinary injection of dextrose and isotonic sodium chloride solution. Under these conditions he will lose from 5 to 20 Gm. of nitrogen a day in his urine; this represents the loss of 30 to 125 Gm. of dry protein tissue, or, translated in terms of muscle, the breakdown of 150 to 600 Gm. of tissue. If one now adds to this dextrose mixture a sufficient amount of an amino acid mixture which will balance the nitrogen loss, or which contains more nitrogen than is excreted, one may say in the first case that the loss of protein tissue has been replaced and that in the second case additional protein tissue has been fabricated from the amino acids which have been introduced. Though some question has been raised as to the validity of studies of nitrogen balance as a measure of tissue protein synthesis, most authorities would accept this device as a method of measuring the efficacy of any protein, whether given by mouth as such or by the parenteral route as an amino acid mixture.

In the case of surgical patients before operation positive nitrogen balance has been achieved repeatedly with the use of parenteral solutions of hydrolyzed protein as the sole source of nitrogenous nourishment.[1] After operation, at least with moderate amounts of amino acids, it is much more difficult to demonstrate a positive nitrogen balance, but in any case it is always possible to lessen to a considerable extent the

1. Elman, R.: Parenteral Alimentation in Surgery, New York, Paul B. Hoeber, Inc., 1947.

large loss of nitrogen which is so commonly seen after trauma. For example, the average daily loss of nitrogen after operation may be between 10 and 20 Gm. If 12 Gm. of nitrogen in the form of a hydrolyzed protein solution is added to the parenteral fluid, the nitrogen excreted will increase, but the negative balance is greatly reduced, to about 3 Gm. of nitrogen, thus preventing the wastage of about 8 to 15 Gm. of nitrogen, or in terms of tissue, 250 to 450 Gm. per day.

A second method by which the nutritional value of protein food can be demonstrated is the measurement of its effect on regeneration of plasma protein. Animals are first depleted by a protein-free diet. When given an adequate solution of amino acids or of hydrolyzed protein, they will fabricate serum albumin almost as well as when fed protein by mouth. In human beings a similar demonstration has also been made, although the evidence is not as extensive. The reason is that one is not justified in using the parenteral channel for long periods of time in human beings, since in most clinical cases the oral route is used as soon as possible. Inasmuch as it usually takes a long period to demonstrate increases in serum protein, which form but a small fraction of the total protein in the body, such long term observations in human beings have seldom been carried out.

A third and perhaps a better method than the measurement of serum protein regeneration would be the direct demonstration of tissue protein synthesis itself. This could be readily done with the liver as the tissue studied. Such experiments are now under way.[1a]

There are two other ways in which the efficacy of protein food has been determined, at least as applied to the oral route. One of them concerns the ability of the material to promote a normal growth in immature rats given the protein preparation as the sole form of nitrogenous nourishment. Indeed, this test is a most rigid one in determining the presence of the essential amino acids in adequate amounts. The other method is the ability of the preparation, when given as the sole source of nitrogenous nutriment, to promote normal gain in weight in adult animals that have been depleted by the ingestion of a protein-deficient diet. Neither of these methods has been extensively used for testing hydrolyzed protein used parenterally.

A sixth method might also be mentioned, and that is the analysis of the protein for its content of essential amino acids. If sufficient amounts are present, it is assumed that the preparation is adequate.

CLINICAL OBSERVATIONS

Entirely apart from these metabolic and biochemical considerations, considerable clinical evidence is available that the use of parenteral protein feeding is of benefit to surgical patients. Such observations,

1a. Ross, C. A., and Elman, R.: Science **108**:441, 1948.

being subjective, will obviously have much less scientific value. Nevertheless, many patients have been treated with and without this addition to the parenteral regimen and several differences noted. For over a decade practically every patient unable to take anything by mouth was given a solution containing dextrose, vitamins and a certain amount of salt. The behavior of such patients is relatively easy to compare with that of subjects to whom an amino açid mixture also has been given.

These observations may be briefly summarized. The preoperative use of amino acid mixtures in addition to the usual injection of dextrose has resulted in a much better condition of the gastrointestinal tract, particularly in patients with various types of obstruction and with fistulas. To be sure, other methods of preparation also contribute to this desirable state. The evacuation of obstructed gastric contents and the decompression of distended intestine is of primary importance. However, parenteral feeding so improved the condition of the tissues in the gastrointestinal tract that edema is less evident or completely absent, the empty collapsed stomach and intestines are much easier to handle and to dissect, anastomoses much simpler and healing much more efficacious. Moreover, patients are able to withstand much more extensive surgical procedures when prepared this way than when given only vitamins, dextrose and water as the sole nutritional intake.

After operation, patients in whom protein starvation has been prevented by the administration of amino acids seem to be less asthenic, are more likely to start early movement and are far more likely to ask for food earlier than patients given dextrose alone. It is therefore possible to shorten the period of postoperative disability and indeed to start patients on a normal oral intake much sooner than was the case when dextrose alone was given. In addition, I have seen much fewer postoperative difficulties due to obstruction at anastomoses, particularly after gastroenterostomy. Infection of wounds seems to be much less prevalent, although this has not been a great problem in recent years. Wound healing is also improved, although here again, with the use of nonabsorbable sutures and with adequate preoperative preparation, the use of vitamins and blood and the avoidance of too much fluid, particularly saline fluid, after operation, these complications have not been very prevalent in recent years.

The ability of the parenteral injection of amino acids to control the feeling of hunger has been subjected to some inquiry. I have made a number of observations which suggest that dextrose alone will not control pain in patients with duodenal ulcer, whereas the addition of amino acids has actually done so. In many patients the injection of amino acids has provoked the voluntary statement that their hunger has been controlled. For a long time there seemed no physiologic basis for this effect, but within the past year observations have been made

in the clinic at Washington University by Crider and Walker [2] on a patient with a large fistula of her stomach, indicating that the intravenous injection of amino acids decreases the resting activity of the stomach, whereas a similar injection of dextrose alone was without effect. These observations suggest that the entrance of amino acids into the blood puts the stomach completely at rest. If hunger is actually due to gastric activity, this furnishes a basis for the bedside observation that hunger may be controlled in this way.

To mention a specific type of surgical problem, which has been especially benefited by the parenteral use of amino acids, I would cite my experience with about 12 patients with multiple intestinal fistulas due either to difficulty following the drainage of an appendical abscess, operations for intestinal obstruction, the presence of regional ileitis or an obstruction following an enterostomy. By adequate preparation before operation it was possible to improve the local lesion as well as the general nutrition so as to get the patients in a condition which permitted a safe one stage resection of the fistula or fistulas, including the damaged bowel, and to perform an anastomosis with complete closure of the abdomen. Most of these patients are extremely malnourished and therefore could withstand a surgical procedure of any extent poorly. Yet oral feeding usually aggravated their local and general condition. In each of these cases the entire surgical procedure was carried out without a fatality.

Inasmuch as protein can also be given parenterally as blood and plasma transfusions, the question is often asked as to the efficacy of this means as a method of introducing protein food in the patient unable to eat. First of all, it must be stated that the use of amino acids is more physiologic in that it imitates more closely the normal way in which protein nourishment is used by the body. By contrast, whole blood or plasma as a source of protein food involves an entirely different principle, which must first be scrutinized. The justification for the use of plasma as a means of introducing parenteral food lies in a theory [3] of protein metabolism which assumes that the plasma proteins are actually the medium of exchange between the various body proteins, even though amino acids are conceded to be the medium of exchange between the food proteins and the tissue protein.

What is the evidence for this theory? One may dismiss for the moment the hemoglobin of the red blood cells, inasmuch as this protein is intracellular and behaves differently. Indeed, there is no quarrel at all about the efficacy with which red blood cells will correct a deficit of hemoglobin regardless of whether it is due to an actual loss as such

2. Crider, R. J., and Walker, S.: To be published.

3. Whipple, G. H., and Madden, S. C.: Medicine **23**:215, 1944.

or is nutritional in origin. The same, unfortunately, is not true of plasma protein, which, when given intravenously, rapidly leaves the blood, especially when the deficit is of nutritional origin. However, following the injection of plasma there is no immediate increase in nitrogen excretion, indicating that the protein has been completely retained by the body. What becomes of the plasma protein after it leaves the circulation is still a mystery, although more information is being obtained as time goes on. Since immediate positive nitrogen balance was achieved, it was assumed that the plasma protein was utilized by the body in the fabrication of tissue protein. In experiments carried out in my laboratory, however, we found that after cessation of the injection, the nitrogen retained during the period of plasma transfusion appeared in the urine in appreciable amounts, so that by the end of the second week much, but still not all, of the nitrogen retained during the period of plasma transfusion appeared in the urine as urea and ammonia.[4] These experiments were carried out in dogs. Similar observations have been reported in human beings by Meyer and his associates.[5] More complete metabolic studies have been carried out in human beings by Albright,[6] who, in 2 cases, has demonstrated a similar phenomenon. He showed that during the period in which the plasma protein is injected, no increase in urinary nitrogen occurs, but that, if the patient is studied for a week or two afterward, it will be observed that an increasing amount of nitrogen is burned and appears in the urine as urea and ammonia. Some is utilized by the body as tissue protein, and a small portion is actually retained in the blood stream. The entire process, however, requires about six to fifteen days before completion.

If one may accept these observations as characteristic of the behavior of a plasma transfusion given to the malnourished patient, one may say that only a portion of the protein so introduced is used in the rebuilding of tissue protein but that the process is delayed. Thus plasma may, to a certain extent, be used as a source of parenteral protein feeding, even though it does so in a roundabout way, requiring a considerable period. However, these studies are neither for nor against the idea that plasma protein itself is the medium of exchange. It seems likely that the plasma protein is broken down to amino acids or small peptides by tissue or blood proteases and thus undergoes the same physiologic cycle as food protein before it can be used by the tissues of the body.

The second type of evidence concerns the ability of plasma transfusions to lead to an elevation in the low level of serum albumin seen in protein-deficient patients. A priori this might seem to be easily

4. Elman, R., and Davey, H. W.: J. Exper. Med. **77**:1, 1943.

5. Meyer, F. L., and others: Am. J. M. Sc. **213**:160, 1947.

6. Albright, F., in Ninth Meeting, Conference on Metabolic Aspects of Convalescence and Wound Healing, edited by E. C. Reifenstein Jr., New York, Josiah J. Macy Jr. Foundation, 1945, p. 89; Twelfth Meeting, ibid., 1946, p. 147.

accomplished, inasmuch as one is introducing directly into the blood stream something which is actually missing. However, these attempts have been disappointing. On close scrutiny the reasons are obvious. In the first place it is known that much of the injected plasma protein leaves the circulation. In the second place it is known that in protein deficiency of nutritional origin the low plasma protein represents only one small segment of that throughout the body. It is easy to see, therefore, why plasma protein introduced as a plasma transfusion would leave the blood stream to meet the needs of the tissues elsewhere. Metabolically the albumin segment of the plasma is only one thirtieth or less of the total body protein,[7] and since this distribution is a physiologic one, as demonstrated by many studies in this and other laboratories, it is not surprising that when protein is administered in any way it would be distributed in this quantitative manner. Thus it would seem that even when plasma protein is introduced directly into the blood only about one thirtieth of it would remain in the circulation, the rest of it going to the rest of the body to supply protein deficiencies there.

The other methods commonly used for determining the efficacy of protein preparations have not been tried as far as plasma transfusions are concerned. It is known that plasma given by mouth will not lead to a weight gain in immature rats and therefore does not contain all the essential amino acids needed for growth. However, bovine plasma when given by mouth will lead to serum protein regeneration in the dog and presumably will therefore lead to tissue protein synthesis elsewhere. However, this has little bearing on the use of plasma when introduced intravenously except that it indicates that certain preparations of plasma do contain a sufficient amount of the essential amino acids for protein tissue regeneration in the adult animal, but not for growth in the immature animal. Plasma by injection has not been tried in regard to its ability to lead to tissue protein synthesis in adult depleted rats.

Other differences between injections of plasma protein and hydrolyzed protein may be mentioned. The incidence of reactions seems somewhat similar, except for homologous serum jaundice, a danger which is true only with plasma transfusions. The cost of plasma is important, when purchased commercially $1.75 as compared with $0.04 per gram for hydrolyzed protein. One liter of plasma, yielding about 60 Gm. of protein, requires the bleeding of 4 donors. Plasma, moreover, contains much sodium chloride and citrate, which is not needed by and may even be harmful in certain depleted patients.

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7. Weech, A. A., and others: J. Clin. Investigation **16**:719, 1937. Sachar, L. A., and others: J. Exper. Med. **75**:453, 1942.

CONCLUSIONS

In the practical care of the depleted patient unable to eat, no single means of giving protein parenterally should be used exclusively. Each has its place and all subserve somewhat different purposes. For the immediate nutrition of tissues, amino acids should be introduced in amounts of 100 Gm. or more a day plus the same amount of dextrose, some salt and vitamins. Generally only 2 liters of water need be given for maintenance in the absence of pathologic fluid losses. Whole blood should be given in addition, largely to restore the red cell mass to normal. Plasma transfusions will also be of value, because they will to some extent increase the level of plasma protein. The salt content of plasma is a real disadvantage, but has been eliminated by the newer preparation of salt-poor human albumin, which has been shown to be much more valuable. Unfortunately, this material is not yet available commercially except at a cost which is beyond the reach of most patients.

DISCUSSION

DR. WALTER W. CARROLL, Chicago: I have no intention of detracting from Dr. Elman's work but merely wish to report that another of the pharmaceutic houses has come out with a product which is made from blood fibrin. The name of the hydrolysate is "aminosol-fibrin." This has been thoroughly tested in the laboratory for study of animals, and it is now possible to test it in the laboratory for study of man. Using a group of 10 medical students as volunteer experimental subjects, my co-workers and I placed each on a weighed diet for a period of time sufficient to produce a state of metabolic protein equilibrium. They were then given amounts of this parenteral hydrolysate, ordinarily about 2 liters. On examining these graphs you will notice that all of them achieved a positive nitrogen balance. The point of significance is that one can achieve a positive balance if enough of a biologically adequate product is administered during each twenty-four hour period. Two liters and sometimes 3 liters are needed each day. This hydrolysate was well tolerated and caused little local or systemic reactions when administered at the rate of 1 liter over a period of three or four hours.

A second point of significance concerns the amount of amino nitrogen that is spilled unchanged into the urine. Studies on the human renal threshold in this regard are lacking as concerns the normal level. It appears that in using this hydrolysate, about 9 per cent of its amino nitrogen is cast off unchanged. This is only one of the reasons that more protein must be given parenterally to equal the same effect obtained through the oral route of administration. It is interesting to note that this amount of spill is unaffected by the amount of concomitant oral ingestion of protein.

There is no question that Dr. Allen's work on the value of plasma as a source of protein is excellent, but he has indicated that the control period was the same for the comparative studies between plasma and the amigen protein hydrolysate. There did not seem to be any "rest" period between, so that the effects of the administration of the first might well have blended with those of the second. Since there occurs a definite lag in protein metabolism in point of time, one must conclude that a portion of the good effects attributed to the plasma might have been due to the very recently administered protein hydrolysate. Our studies

would indicate that after the period of parenteral administration we collected some products of this protein metabolism up to thirty-six and sometimes forty-eight hours later.

Dr. Walter G. Maddock, Chicago: I agree with Dr. Elman's comment that a patient who needs a daily maintenance amount of fluid should receive water plus at least 100 Gm. of carbohydrate and 100 Gm. of a protein hydrolysate a day. The protein is particularly good for the patient needing fluids intravenously for more than two or three days. A larger amount of carbohydrates and protein may be necessary with undernutrition due to disease. Concerning a daily allowance of salt, there are some differences of opinion. Some advise against giving any salt, but if the patient could select his own diet he certainly would have a salt-containing diet. For the average patient without abnormal loss of salt, I allow about 5 Gm. of sodium chloride per day. This is 500 cc. of 5 per cent dextrose in isotonic solution of three chlorides per day or a liter every second day. A liter of saline solution a day, about 9 Gm. of sodium chloride, is too much, and I have seen edema develop in a seriously ill patient with infection and hypoproteinemia receiving this amount for several days.

Dr. Elman has presented some excellent reasons for giving protein hydrolysate solutions to patients requiring maintenance nutrition by means of parenteral fluids. I would like him to tell his experience with these solutions for the restoration of low plasma proteins to normal in the seriously ill patient.

Dr. Robert Elman, St. Louis: There are several brands of protein hydrolysate which are available for parenteral use. The brand name is not as important as the safety of the preparation plus its ability to meet the needs for nitrogen metabolism.

In answer to Dr. Maddock's question my experience indicates that neither of the two methods of introducing parenteral protein is practicable for restoring to normal all of the body proteins in a severely depleted patient. While the plasma proteins should not be viewed as a separate compartment from the rest of the body proteins in such patients, it is true that plasma transfusions will lead to a quicker and greater, though more transient, correction of hypoproteinemia than amino acids themselves; this is true whether the amino acids come from the digestion of protein food or from parenteral injections, although the amount given and the length of time available are, of course, of primary importance. The best clinical results come from the realization that neither amino acids nor plasma need be used exclusively. As long as both methods are available, both should be used. Amino acids should certainly be employed to furnish the tissues with the necessary building stones for the synthesis of protein. Hemoglobin, being an intracellular protein, can be most effectively introduced and will correct deficiencies permanently. Plasma is also of great value and should therefore be used in most of these cases. Its salt content is a definite disadvantage, which has recently been overcome by preparing a salt-poor pure human albumin, which in our hands has proved a much more effective way of temporarily increasing the concentration of plasma albumin than was ever the case with plasma transfusions. As mentioned before, however, the oral channel is the most efficient way of restoring lost protein tissue; parenteral methods are used for as short a period as possible in order to reduce the hazard of operation and accelerate postoperative recovery.

REGIONAL ENTERITIS

Further Pathologic Observations

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CHRONIC inflammatory lesions of the large and small intestine have been reported in the literature, from time to time,[1] but not until Crohn, Ginzburg and Oppenheimer [2] described the inflammatory condition which they called "regional ileitis" was it suggested that there was one group of such lesions which could be considered a clinical pathologic entity. Because no single gross or microscopic feature has been considered typical of the disease process, there has been much opposition to considering this a disease entity.[3] Hadfield's [4] excellent summary of the pathologic changes gives support to the contention that the lesion is a distinct one. Since publication of a study of 22 cases of this disease,[5] careful examination of an additional 28 cases reveals the characteristic pattern of this disease, which will be discussed here.

It is well recognized that the disease is protean in its clinical manifestations. The pathologic observations vary considerably, in accordance with the duration and severity of the symptoms. It is not the purpose of this paper to describe the variable gross picture which may exist, but to correlate the changes which are of such constancy as to be used as diagnostic criteria. Just as Hodgkin's disease is diagnosed by no one single microscopic criterion, so also regional enteritis is diagnosed by the coexistence of several pathologic changes.

From the Department of Surgery, The University of Chicago.

Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 20, 1948.

1. Moschcowitz, E., and Wilensky, A. O.: Non-Specific Granulomata of Intestine, Am. J. M. Sc. **166**:48, 1923; Non-Specific Granuloma of Small Intestine, ibid. **173**:374, 1927.

2. Crohn, B. B.; Ginzburg, L., and Oppenheimer, G. D.: Regional Ileitis: A Pathologic and Clinical Entity, J. A. M. A. **99**:1323 (Oct. 15) 1932.

3. Homans, J., and Hass, G. M.: Regional Ileitis: A Clinical, Not a Pathological Entity, New England J. Med. **209**:315, 1933.

4. Hadfield, G.: The Primary Histological Lesion of Regional Ileitis, Lancet **2**:773, 1939.

5. Owens, F. M., Jr.: Regional Enteritis: Pathologic Study of Twenty-Two Cases, Arch. Surg. **48**:465 (June) 1944.

The gross appearance of the bowel in regional enteritis varies according to the chronicity of the process and the presence of complicating fistulas. However, the bowel wall is invariably thickened by edema and fibrosis. This is in contrast to the decided thinning of the bowel wall often seen in ulcerative colitis. The serosa is thickened and the areas of involvement are demarcated by the extension of mesenteric fat over

Fig. 1.—Gross specimen of resected ileum and cecum, showing the encroachment of mesenteric fat on the bowel wall (arrow).

Fig. 2.—Specimen of ileum opened, showing the extensive thickening of submucosa, (*a*), the loss of mucosal pattern, the encroachment of fat on the bowel wall and narrowing of the bowel lumen.

the serosal surface of the bowel.[6] The mesentery is thickened by extensive edema and contains many large hypertrophied lymph nodes (fig. 1).

6. Bockus, H. L.: Gastroenterology, Philadelphia, W. B. Saunders Company, 1946, pp. 158-196.

Cut section of the bowel wall reveals that the edema involves all of the coats, but is most striking in the submucosal layer (fig. 2). Stenosis of the lumen of the bowel is in direct proportion to the edema and fibroplasia of the submucosa. The mucosa appears bossilated and edematous and the beginning of small sinus tracts may be seen in diverse regions. Ulcers are present, but there is not the extensive necrotizing sloughing deep ulceration which is typically seen in ulcerative colitis.

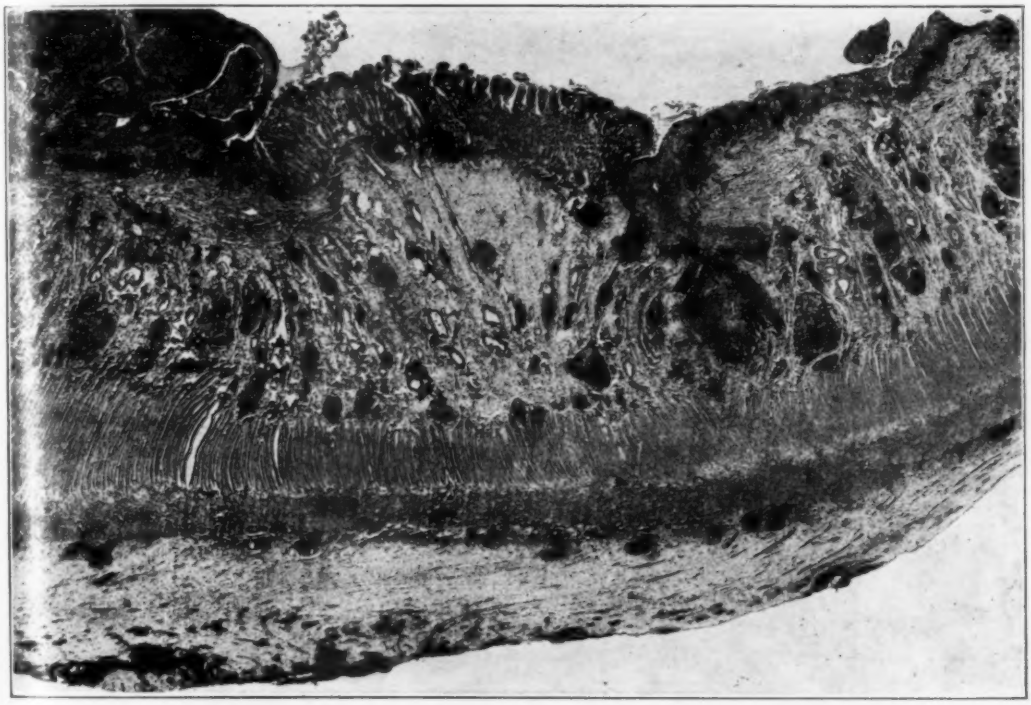

Fig. 3.—Section of wall of the ileum, showing extensive thickening of submucosa by edema, fibrosis, lymphoid infiltration, lymphatic dilatation and increased vascularity, prominence of Auerbach's plexus and serosal granulomas.

Of great significance is the differentiation between chronic nonspecific ulcerative colitis and regional enteritis of the colon. Several of the changes seen are the same in the two processes, but there are definite distinguishing features.

Microscopic examination of the bowel affirms the contention that this is a pathologic entity.

The mucous membrane may show villous hypertrophy in some areas and erosion in other areas. In both cases there is infiltration of the subepithelial regions of the mucosa by granulation tissue. Erosions

lined by granulation tissue exist, but these erosions usually do not penetrate to involve the muscularis mucosae. However, sinus tracts are frequently observed; these have narrow points of origin, are lined

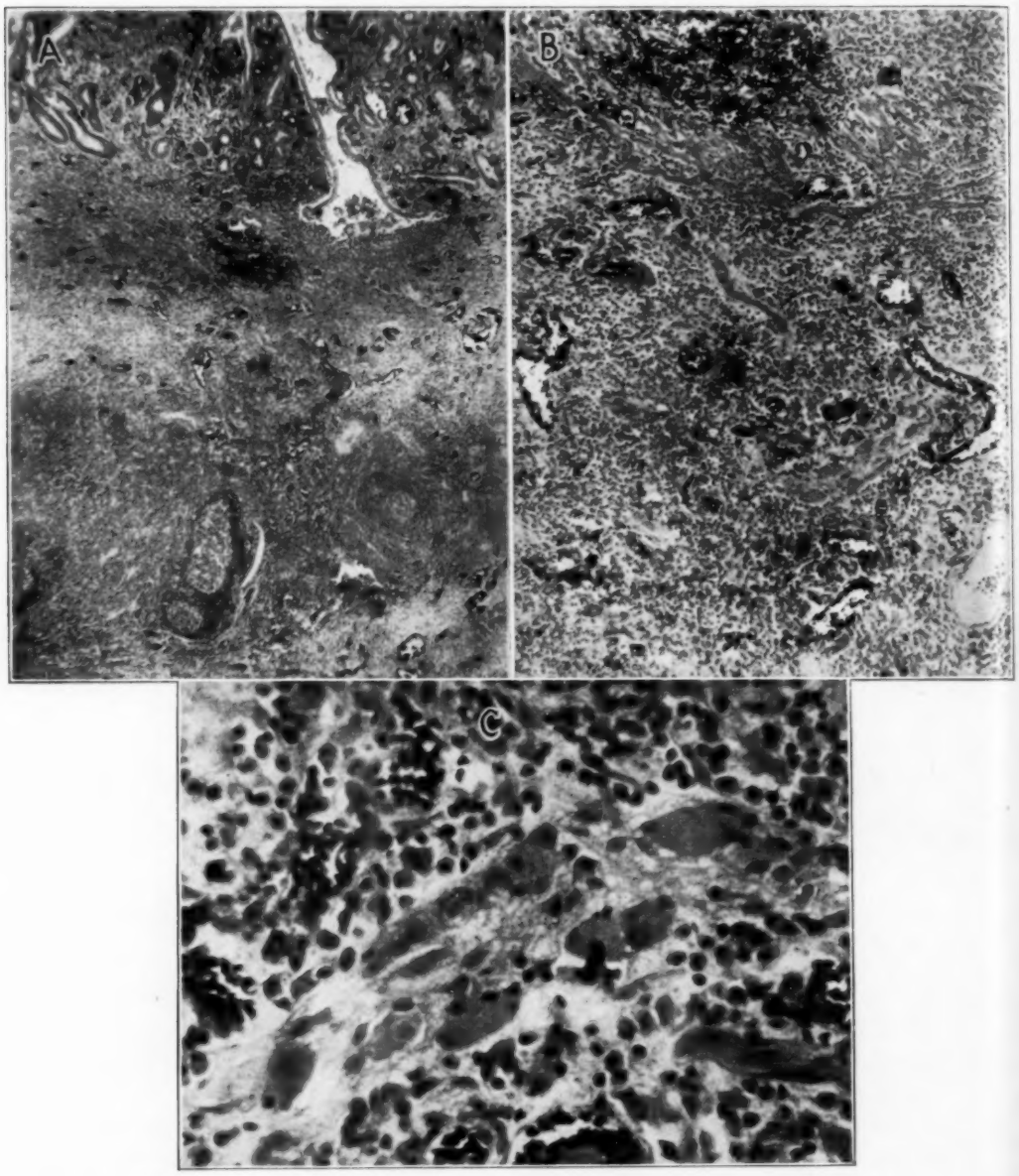

Fig. 4.—Photograph of submucosa. *A*, early sinus formation, submucosal lymphoid aggregates and increase of neural elements. *B*, ganglion cells and dilated lymphatics in the same region. *C*, high power magnification of a group of ganglion cells in this region.

by granulation tissue containing many giant cells and may penetrate through the entire thickness of the bowel wall, into the mesentery or into contiguous loops of bowel.

The submucosa shows changes not seen in other inflammatory processes (fig. 3). There is extensive edema of this layer. Diffuse inflammatory infiltrate containing a predominance of eosinophils invades

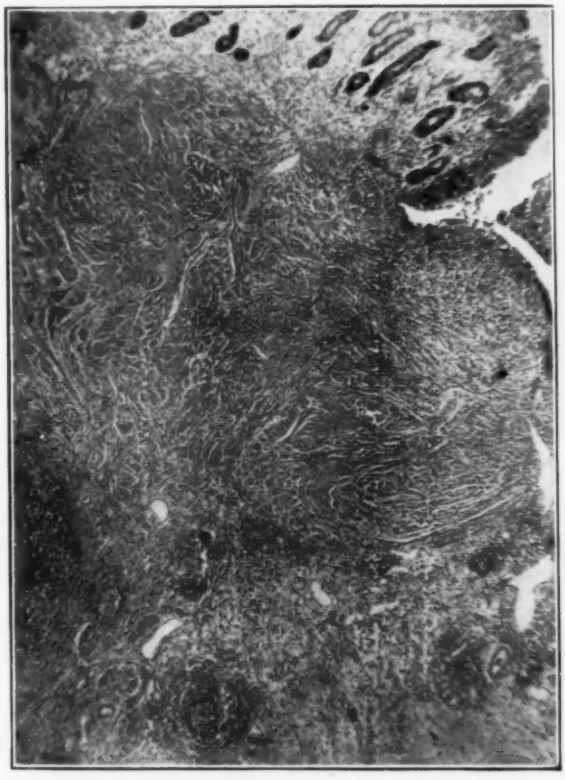

Fig. 5.—Hyperplasia of muscularis mucosae.

the submucosa, but rather characteristic is the presence of numerous active lymphoid follicles. Lymphatics are usually extensively dilated so that there is focally the appearance of lymphangioma. In the more chronic stages, sclerosed lymphatics are observed and considerable infiltration of the submucosa by fibrous tissue is evident. Ganglion cells and nerve fascicles scattered through the submucosa can easily be seen (fig. 4). Neural structures are definitely more numerous than in the normal bowel. Spectacular hypertrophy of the muscularis mucosa is frequently seen (fig. 5). Whether the lesion is in the large or small

bowel, the submucosa is affected in precisely the same manner. These changes are not simulated, for example, in ulcerative colitis or other inflammatory lesions of the bowel.

The muscularis propria shows little inflammatory infiltrate, but along the lymphatics are focal aggregates of lymphoid cells (fig. 6). Ganglion cells and nerve fibers of Auerbach's plexus assume greater prominence than can be accounted for by the shortening of the intestine which accompanies the inflammatory and edematous changes.

Small tuberculoid granulomas of the serosa exist intermixed with aggregates of lymphoid cells (fig. 7). Dilated lymphatics are promi-

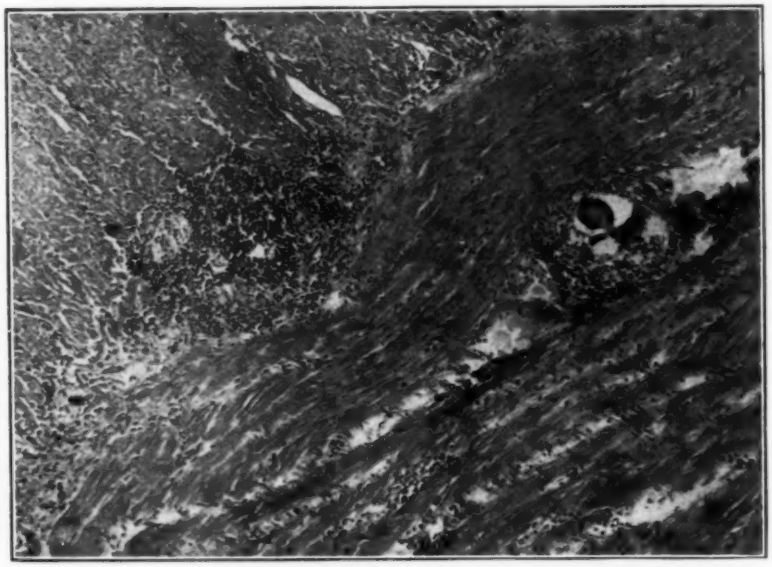

Fig. 6.—Focal granulomas in muscularis propria.

nent, but, as in the submucosa, sclerosed lymphatics may be seen. The serosa is thickened by the edema and inflammatory infiltration.

In the mesentery there is extensive edema, which, in the more chronic stages, is associated with fibrosis. Lymphatics are dilated and lymphoid aggregations are prominent in relation to the lymphatics. Giant cells may be seen in these focal accumulations of lymphoid cells, just as they are seen in the bowel wall and in the lymph nodes. Striking lymphoid hyperplasia exists in the mesenteric lymph nodes. Tuberculoid granulomas are observed in many nodes, but these are fibrous and do not caseate. Giant cells may contain refractile foreign bodies of vegetable nature.

Grouping together the changes described, a picture is constructed which is not duplicated by other inflammatory conditions of the large

and small bowel. In view of the submucosal change, there is much to support the theory of allergic origin of this disease, although the possibility that it is a primary lymphatic infectious process still exists. The entity is reported to be common in Puerto Rico, where diseases of lymphatic origin prevail.[7]

Studies are in progress at present to determine the presence or absence of an allergic factor in the causation of this disease.

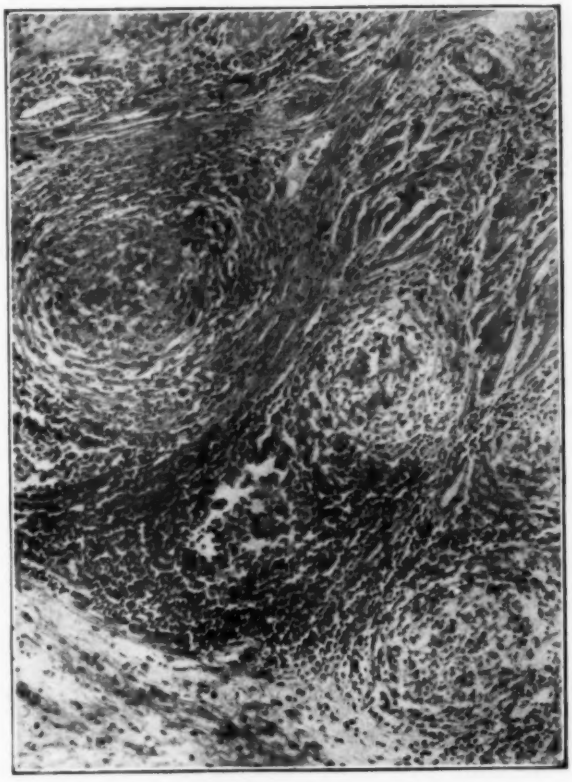

Fig. 7.—Tuberculoid granuloma of the serosa.

SUMMARY

Individually, the processes represented in the total "picture" of regional enteritis are not unique. It is the repetition of the "picture" in conjunction with its stereotypy in case after case of clinically typical regional enteritis which supports the contention that this is a clinical pathologic entity.

7. Ascencio-Camacho, F.: Regional Enteritis in Puerto Rico, Gastroenterology **6**:493, 1946.

ACTINOMYCOSIS OF THE THORAX AND ABDOMEN

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EXTENSIVE visceral actinomycosis has for many years been considered to be a severe disease with a uniformly poor, if not hopeless, prognosis.[1] In recent years emphasis has been placed by some authors on the importance of adequate surgical measures in the alleviation of this disease.[2] Others[3] have emphasized the use of chemotherapeutic agents. Reports during the past few years of successful treatment in cases of actinomycosis of the abdominal or thoracic viscera far outnumber those reported in previous decades. Kolouch and Peltier,[4] in reviewing the literature, summarized the reported cases according to type of treatment received (table).

Statistically, the percentage of patients listed as cured or improved is not wholly significant, for the numbers are small and the overlapping of treatments employed allow only a relative evaluation. Kolouch and Peltier pointed out, however, that significant trends are apparent, one of which is the decreasing mortality rate in cases of severe abdominal or thoracic actinomycosis in which sulfonamide drugs or penicillin have been used in adequate doses.

It is the purpose of this report to describe 6 more cases of extensive actinomycosis of the thoracic or abdominal viscera.

Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 20, 1948.

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1. (*a*) Wangensteen, O. A.: The Role of Surgery in the Treatment of Actinomycosis, Ann. Surg. **104**:752 (Oct.) 1936. (*b*) Good, L. P.: Actinomycosis of the Abdomen, Arch. Surg. **22**:307 (Feb.) 1931. (*c*) Robson, G. M.: Actinomycosis Starting as Appendicitis with Exterior Visceral Involvement, Am. J. M. Sc. **181**: 692 (May) 1931.

2. (*a*) Wangensteen.[1a] (*b*) Lyons, C.; Owen, C. R., and Ayers, W. B.: Sulfonamide Therapy in Actinomycotic Infections, Surgery **14**:99 (July) 1943.

3. (*a*) Dobson, L.; Holman, E., and Cutting, W. C.: Sulfanilamide in Therapy of Actinomycosis, J. A. M. A. **116**:273 (Jan. 25) 1941. (*b*) Farris, E. M., and Douglas, R. V.: Abdominal Actinomycosis, Arch. Surg. **54**:434 (April) 1947. (*c*) Walker, S. M., and Hamilton, J. W.: The Treatment of Actinomycosis with Penicillin, Ann. Surg. **121**:373 (March) 1945.

4. Kolouch, F., and Peltier, L. F.: Actinomycosis, Surgery **20**:401 (Sept.) 1946.

REPORT OF CASES

CASE 1.—C. C., a 26 year old white man, was admitted to his local hospital in November 1937, for acute appendicitis. He underwent an appendectomy, at which time the appendix was seen to be perforated. He recovered quickly, but in March of the following year a large abscess developed in the left lower quadrant of the abdomen, which was incised and drained. Sulfur granules were present, and Actinomyces were identified. The sinus continued to drain, the patient lost weight, anorexia developed, and he grew progressively worse. In February 1939, at a University Hospital, he had an incision and drainage of a right perinephritic abscess and an abdominal wall abscess at the site of his appendectomy wound. He returned home, but a month later was admitted to a large city hospital, where a right subphrenic abscess was drained and a nephrectomy done on the right side. Though purulent drainage was profuse from all sinuses, he improved for a time, but later his general condition deteriorated, and on July 31 he was admitted to the Wayne County General Hospital.

Physical examination revealed a pale undernourished white man with a temperature of 100 F., pulse rate 110 and respirations 25. There were draining

Results of Treatment of Abdominal and Thoracic Actinomycosis (Kolouch and Peltier)

Primary Type of Therapy	Thoracic			Abdominal		
	No. Cases	Cured or Improved	Death	No. Cases	Cured or Improved	Death
Operation	26	5	19	70	24	45
Radiation	72	8	54	235	96	123
Vaccine	10	2	7	6	1	5
Thymol	1	1	0	1	1	0
Sulfonamide drugs	10	8	1	16	12	3
Penicillin	7	5	2	2	1	1

sinuses in the right and left lower quadrants of the abdomen and the right flank. His hemoglobin was 8.3 Gm. per hundred cubic centimeters, with 2,000,000 red cells. His leukocyte count was 15,700, with 89 per cent neutrophils. Results of urinalysis were negative. All this time cultures from his sinuses did not reveal Actinomyces, and the predominant organism was Staphylococcus albus.

His hospital course was one of sepsis, his temperature ranging from 100 to 103 F. On September 1 a large abscess in the right iliolumbar area was incised and drained. Roentgenograms showed absence of the psoas shadow on the right. On September 15 he began having generalized epileptiform convulsions, which continued throughout his hospital course. He received repeated blood transfusions and a total of three weeks' treatment with "promin" (sodium p,p'-diaminodiphenylsulfone-N,N'-didextrose sulfonate). He also received seven roentgen treatments, totaling 840 r, through an anterior port in the right lower quadrant of the abdomen. Toward the end of his hospital course generalized edema and ascites developed. He died on November 9, twenty-four months after the onset of his illness.

At autopsy the peritoneal cavity showed no evidence of recent peritonitis. The appendix was absent, and the cecum was normal in appearance.

The sinuses from the right flank and right and left lower quadrants of the abdomen all were traced through retroperitoneal spaces to small paravertebral

abscesses located adjacent to the vertebrae from the eighth thoracic segment to the sacrum. On sectioning the vertebrae, a large abscess was seen within the body of the tenth thoracic vertebra and small 1 cm. abscesses were observed within the substance of all the lumbar vertebrae. There was no involvement of the meninges or central nervous system. Smears and cultures from the vertebral abscesses revealed many filaments characteristic of Actinomyces. The results of the remainder of the examination were negative except for observation of terminal bronchopneumonia and changes in the parenchymatous tissues incident to a chronic illness.

This case represents a fairly characteristic progression of this disease beginning with acute appendicitis. More often than not the cecum heals with no evidence of residual actinomycosis, but if the retroperitoneal tissues are inoculated with the fungus, it quickly spreads to involve the spaces around the kidney, liver, diaphragm and vertebrae. Periostitis and cortical erosion of the vertebrae, as a result of invasion by a paravertebral phlegmon, may occur and may be significant if the process is revealed by roentgen examination.[5] Multiple small abscesses within the body of the vertebrae are probably metastatic through the vertebral venous plexus.

CASE 2.—M. F., a 16 year old white girl, was admitted on Feb. 21, 1941, to a large city hospital, complaining of pain in the lower part of the abdomen and a tumor in the right lower quadrant. Operation revealed an appendical abscess, which was drained. Numerous organisms characteristic of Actinomyces were seen in the pus. She was given sulfathiazole therapy, 6 Gm. a day, but because of toxic manifestations treatment with this drug was discontinued after one week. She was discharged to her home after two months of hospitalization, but two months later was admitted to a University Hospital. Her abdominal sinus persisted, and on July 8 an incision was made in the iliolumbar region and anteroposterior drainage instituted. The diagnosis of actinomycosis was confirmed by laboratory examination. Roentgenologic examination revealed no bone involvement, and examination of the sinus tract with iodized poppyseed oil showed that the sinus extended into the retroperitoneal space toward the paravertebral muscles. The patient was treated with thymol and sulfathiazole. On July 15, another abscess in the region of the posterior wound was incised and drained. A week's course of intravenous sulfanilamide therapy was given, along with transfusions, vitamins and thymol.

On August 11, the patient was admitted to the Wayne County General Hospital. At this time examination of her blood revealed: hemoglobin 7.3 Gm. per hundred cubic centimeters and 2,380,000 red blood cells. Her white blood cell count was 26,850. The patient was again given repeated transfusions, and orally administered sulfathiazole was again tried without success. Thymol packs were used in the wounds. Large doses of vitamins, iron and iodides were given, without visible improvement in her condition. Beginning October 5, she was given sulfadiazine, 4 Gm. daily, which was continued for three and one-half weeks. Her blood sulfadiazine levels ranged from 6.5 to 15.6 mg. per hundred cubic centimeters. During this period roentgen therapy was also given to the

5. Cope, Z.: Actinomycosis, London, Oxford University Press, 1938.

lower part of the abdomen. Clinically, during the period of sulfadiazine therapy, her condition improved as she remained relatively afebrile, though the sinuses showed little evidence of closing. On November 4, on insistence of the parents, she was discharged to her home. Her general condition was thought to be better than on admission, but her prognosis was felt to be poor. She died Dec. 13, 1942, thirteen months after leaving the hospital and twenty-two months after the onset of her illness.

The clinical course of this patient is not unlike that in case 1. Though the involvement of her retroperitoneal tissues was extensive, roentgenograms of the lumbar part of the spine showed no abnormalities at the time of her discharge from the hospital. How far the process may have extended at the time of her death is purely a speculative question. Though the outcome was little different from that in the previous case, the patient's clinical course during her hospital stay appeared to be appreciably altered by the administration of sulfadiazine. During this period, she became afebrile and the amount of drainage from her sinuses decreased considerably.

CASE 3.—J. K., a 24 year old white housewife, was first operated on for suspected acute appendicitis in October 1940. Though an appendectomy was done, her local surgeon ascribed her difficulty to a "ruptured ovarian cyst." She quickly recovered and became pregnant soon thereafter, but aborted two months later. Following this abortion she suffered weakness, fatigue and anorexia and after a few weeks entered another local hospital for treatment. Shortly after this admission she had a posterior colpotomy for drainage of a pelvic abscess and incision and drainage of a pelvic abscess through a lower midline abdominal incision. A sinus persisted at the site of the latter operation, and a subsequent unsuccessful attempt was made to remove the sinus. On Sept. 20, 1941 she was transferred to the University Hospital, where three weeks later another colpotomy was done. Histologic study of granulation tissue removed at this time showed many colonies of Actinomyces.

Examination of the pelvis at this time showed it to be completely frozen by inflammatory reaction, and the patient was given an intensive course of iodides and roentgen therapy. Of the latter she received 1,600 r to each of two anterior and two posterior pelvic ports. Despite this treatment, her general condition declined gradually, and on November 13 she was transferred to the Wayne County General Hospital.

Examination at this hospital revealed an emaciated patient whose temperature was subnormal, pulse rate 50 and blood pressure 105 systolic and 50 diastolic. She had a discharging sinus in the lower part of the abdomen and had large quantities of foul brownish vaginal discharge. Her hemoglobin was 6.8 Gm. per hundred cubic centimeters and her white blood cell count was 17,600. She was given supportive therapy and multiple transfusions. She died on November 18.

Autopsy revealed completely necrotic pelvic organs. The uterus, oviducts and ovaries were identified with great difficulty. The pelvis was filled with brownish gray purulent material, and the mass of necrotic pelvic structures was adherent to the anterior surface of the rectum and rectosigmoid, the posterior aspect of the bladder, the tip of the cecum and one loop of ileum. These structures had thick grayish brown surfaces, but microscopic sections did not show the necrosis

to extend into the mucosa. There was obstruction at the left ureterovesical junction with accompanying hydroureter and severe pyelonephritis. Histologic examination of the pelvic organs revealed necrosis and severe inflammatory reaction. Purulent and necrotic material in the central portion of the mass contained numerous filaments of Actinomyces and a few sulfur granules. Endometrium could be identified in some sections.

Actinomycosis of the pelvic organs is infrequent. Rashbaum and McIntosh [6] could find only 85 cases in the literature, in which only 7 patients survived. They reported 1 case of chronic pelvic inflammatory disease due to actinomycosis, which improved after hysterectomy and roentgen ray therapy. The inability of the organism to produce peritonitis probably is responsible for the few cases of pelvic involvement. The genital canal most likely provides the portal of entry in cases in which only the pelvic viscera is involved. Axhausen [7] pointed out, with particular reference to cervicofacial actinomycosis, that the fungus probably depends on a coexisting or previously existing pyogenic organism which may so alter the tissues that the Actinomyces change from parasitic forms to pathogenic agents. This particular set of circumstances infrequently exists in the pelvis, for Actinomyces are uncommon contaminators of the genital tract.

Case 4.—A. L., a 61 year old white man, was transferred from the psychiatric division to the General Hospital Division of the Wayne County General Hospital and Infirmary, Oct. 2, 1946, complaining of pain in the right lower part of the chest, mild dyspnea and temperature of 103.8 F. His physical examination revealed observations compatible with pneumonia, and roentgenographic examination confirmed this diagnosis. In addition, a large 3 by 4 cm. cystic tumor was noticed in the right submaxillary region, which had been present for more than twenty years. From time to time it had become infected, but had spontaneously drained itself and healed. Surgical extirpation had often been advised, but had been refused. Shortly after admission, sulfadiazine therapy was instituted, and later penicillin, but his course grew progressively worse. A pleural effusion developed, and repeated examinations of the fluid withdrawn from the pleural cavity, including paraffin sections of the sediment and smears, cultures and guinea pig inoculation, failed to reveal anything significant. On one occasion "septate mycelia and unidentified spores" were reported. Bronchoscopy was not allowed. Though the right side of the chest had cleared somewhat, his general condition continued to deteriorate. A tentative diagnosis of carcinoma of the lung was made. Inasmuch as permission for any surgical procedure was refused, the patient was transferred back to the psychiatric division.

On December 16 he was returned to the General Hospital, afebrile but in poor general condition. He had lost 30 pounds (14 Kg.) since his previous admission, and two weeks prior to admission a painful fluctuant tumor had devel-

6. Rashbaum, M., and McIntosh, H. C.: Pelvic Actinomycosis Treated by Surgery and Roentgen Ray, with Recovery, Am. J. Obst. & Gynec. **47**:849 (June) 1944.

7. Axhausen, G., cited by Lamb, J. H.; Lain, E. S., and Jones, P. E.: Actinomycosis of the Face and Neck, J. A. M. A. **134**:351 (May 24) 1947.

oped on the lower anterior aspect of the thoracic wall. Just prior to admission a similar tumor appeared in the midaxillary line at the sixth interspace. He had a productive cough. On admission 400 cc. of purulent material was removed from the right pleural cavity. At the same time a biopsy of the thoracic wall abscess was taken by means of a Turkel needle. In this material many sulfur granules were seen and Actinomyces were cultured. During the next two weeks, involvement of the lower right aspect of the thoracic wall became extensive and several small sinuses, draining purulent material, developed. Permission for operation was finally obtained and carried out December 30. At this time large areas over the fourth, sixth and eighth intercostal spaces from the midaxillary line to the lateral border of the sternum were involved. These were incised and drained, and a 6 cm. segment of the eighth rib was removed and the empyema drained. Approximately 600 cc. of pus were removed. Although large portions of necrotic thoracic wall were curetted out at the points of incision, no effort was made to remove all of the necrotic tissue, for it was felt that such a procedure would leave a thoracic wall defect that would seriously impair the cardiorespiratory functioning of the chest. Actinomyces were again recovered from the pus and the thoracic wall.

Two days prior to operation treatment with 3 Gm. of sulfadiazine and 3 Gm. of sulfamerazine daily was started, and this was continued for two weeks, with a total of 42 Gm. of each. In addition, on the day of operation he was given penicillin, 50,000 units every three hours. The penicillin therapy, however, was continued during his entire hospital course, and at the time of his discharge a total of over 20,000,000 units had been given.

His response to drainage of the pleural cavity was good, and his course was one of steady improvement. About two months after drainage it was necessary to enlarge the thoracotomy wound to insure adequate drainage. The empyema cavity grew smaller rapidly and during March 1947, less than three months after operation, the thoracotomy wound was allowed to heal completely. The other incisions had healed without difficulty. Just prior to the patient's transfer back to the psychiatric division the cystic tumor in the right submaxillary area became inflamed, hot and tender. Warm moist dressings were applied, and a few days later it drained spontaneously. Smears and cultures revealed Actinomyces. A diagnosis of actinomycosis of a branchial cleft cyst was made. Excision of the branchial cleft cyst five months later revealed a collapsed epithelial lined cyst, in which there was no evidence of Actinomyces.

Check-up roentgenograms of the chest revealed no evident pathologic processes five and eight months, respectively, after thoracotomy for the extensive empyema necessitatis (fig. 1).

At the time of writing the patient was in excellent health, maintained normal weight and hemoglobin and had no complaints.

Actinomycosis of the thorax is by no means rare, though until recent years it was thought to be nearly a hopeless disease. Primary mediastinal actinomycosis may occur by penetration of the esophageal wall by the fungus.[5] The majority of cases of thoracic involvement, however, are the result of inhalation or aspiration of infected material into the alveoli, producing actinomycosis of the lung proper. Kay[8] has

8. Kay, E. B., and Meade, R. H., Jr.: Penicillin in the Treatment of Chronic Infections of Lungs and Bronchi, J. A. M. A. **129**:200 (Sept. 15) 1945.

advocated resection of the involved lobes as the treatment of choice in infections confined to the lung, and this is in accord with the surgical principles advocated by Wangensteen [1a] and others.[2b] Proper drainage of the pleural cavity and the accompanying abscesses of soft tissue, together with adequate chemotherapy have accounted for a good result (case 4) when pulmonary cavitation did not occur and mediastinal structures were not involved.

The prognosis for patients with actinomycosis of the chest alone or in combination with other regions is poor. Morton [9] reported only 2 survivals out of 7 cases. Hanes [10] confirmed this impression in a case report and stated that in combination with abdominal actinomycosis, it is the most fatal of all infections. Schmitt and Olsen [11] and others [12] expressed a similar opinion. Nonetheless the reports of successfully

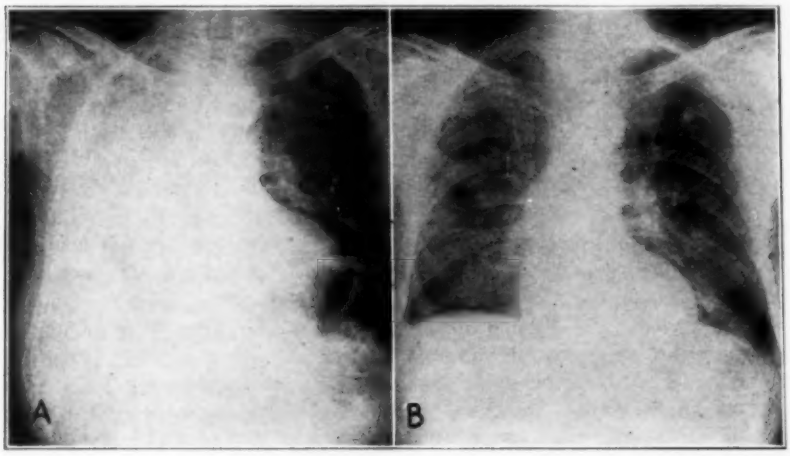

Fig. 1.—*A*, actinomycotic empyema necessitatis with extensive involvement of the thoracic wall. *B*, three months after thoracotomy and intensive penicillin therapy (case 4).

treated patients with thoracic actinomycosis are becoming more numerous. Wilkinson [13] in 1941 reported survival of an 11 year old girl with widespread actinomycosis of the lung, thoracic wall and other soft tissues following the use of 1 to 5 Gm. of sulfanilamide daily for nearly

9. Morton, H. S.: Actinomycosis, Canad. M. A. J. **42**:231 (March) 1940.

10. Hanes, F. M.: Actinomycosis, Internat. Clin. **1**:213 (March) 1942.

11. Schmitt, G. F., and Olsen, A. M.: Actinomycosis of Thorax: Report of Two Cases, Proc. Staff Meet., Mayo Clin. **16**:506 (Aug. 6) 1941.

12. Schulman, H.: Actinomycosis, Pleural and Abdominal, Treated with Penicillin, Bull. Vet. Admin. **21**:230 (Oct.) 1944.

13. Wilkinson, E. E.: Actinomycosis Treated with Sulfonamide, J. Pediat. **18**:805 (June) 1941.

three months. Ladd and Bill [14] in 1943 reported the recovery of a 9 year old boy with actinomycotic empyema necessitatis treated with sulfadiazine over an eight month period. Other cases of thoracic involvement wtih improvement or recovery were reported by Jones and Brownell,[15] Dobson and Cutting,[16] Walker and Hamilton,[3c] Mitchell,[17] Atwood,[18] Pillsbury and Wasserug,[19] Bisgard [20] and Benbow, Smith and Grimson.[21]

CASE 5.—H. P. was an 84 year old white man admitted to the Wayne County General Hospital from the Infirmary Division on Nov. 20, 1943. He had been a resident in the Infirmary Division for three years without any particular complaints. Two days before admission he complained of pain in the upper part of the abdomen of moderate degree. Examination at the time revealed a temperature of 101 F. and generalized tenderness across this area. A large incarcerated left inguinal hernia of several years' duration was present.

At the time of his admission to the General Hospital, physical examination revealed an orange-sized mass in the right upper quadrant of the abdomen which was mildly tender. He was having intermittent cramps, and a tentative diagnosis of intestinal obstruction was made, probably caused by a carcinoma of the transverse colon. A roentgenogram of the abdomen, however, failed to show the usual signs characteristic of intestinal obstruction. Laboratory examination revealed normal urine, 9.0 Gm. of hemoglobin per hundred cubic centimeters and 2,680,000 red cells. The white blood cell count was 16,250, with 88 per cent neutrophils. The reaction to the Kahn and the Kline tests was 4 plus. Throughout his hospital course his temperature ranged from 100 to 103 F. and nonprotein nitrogen from 58 to 72 mg. per hundred cubic centimeters.

On November 27 he suffered another acute attack of abdominal pain, and the condition was considered to be a surgical emergency. However, it was felt that his age and general debility precluded a successful surgical procedure, and a conservative course was followed. His condition gradually deteriorated, and he died on November 29.

At autopsy, recently developed generalized peritonitis was present, and the entire peritoneal cavity held a quantity of thin watery pus. However, between the

14. Ladd, W. E., and Bill, A. H.: Actinomycosis of the Chest with Spread to the Abdomen, New England J. Med. **229**:748 (Nov. 11) 1943.

15. Jones, T. E., and Brownell, T. S.: Treatment of Actinomycosis with Penicillin, Cleveland Clin. Quart. **12**:32 (Jan.) 1945.

16. Dobson, L., and Cutting, W.: Penicillin and Sulfonamides in the Therapy of Actinomycosis, J. A. M. A. **128**:856 (July 21) 1945.

17. Mitchell, H. S.: Sulfapyridine in Actinomycosis, Canad. M. A. J. **46**:584 (June) 1942.

18. Atwood, H. S.: Actinomycosis of the Lung: Minimal Infection, Northwest Med. **41**:419 (Dec.) 1942.

19. Pillsbury, N. R., and Wasserug, J. D.: Pulmonary Actinomycosis: Treatment with Sulfonamides, New England J. Med. **230**:72 (Jan. 20) 1944.

20. Bisgard, J. D.: Actinomycosis Thoracis: Report of Two Arrested Cases, J. Thoracic Surg. **8**:549 (June) 1939.

21. Benbow, E. P., Jr.; Smith, D. T., and Grimson, K. S.: Sulfonamide Therapy in the Treatment of Actinomycosis: Two Cases of Aerobic Partially Acid-fast Actinomyces, Am. Rev. Tuberc. **49**:395 (May) 1944.

transverse colon, duodenum and pyloric portion of the stomach was a well developed large chronic abscess. Large colonies of Actinomyces were easily identified by microscopic examination in the wall of the abscess, which was largely omentum. The appendix was absent, and there was evidence of old inflammation in the peritoneum about the cecum. The remainder of the examination showed changes consistent with old age.

Case 6.—H. M., a 30 year old white man, was admitted to the Kanawha Valley Hospital on March 9, 1946. His illness dated back fourteen months, at which time a perforated gastric ulcer was closed. The operation was complicated by a draining sinus in the upper portion of wound and an incisional hernia. Six months later the sinus tract was excised and the hernia repaired without success. After the second operation, his general condition steadily deteriorated, and he again entered the hospital complaining of intermittent fever, productive cough, night sweats and chills. There were increasing weakness and a loss of weight of 25 pounds (11 Kg.).

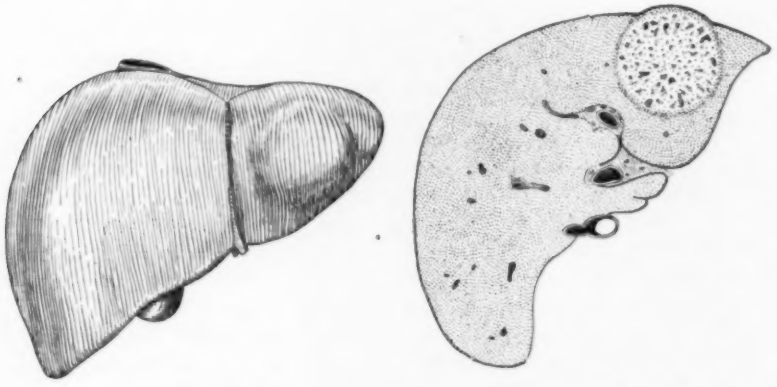

Fig. 2.—Drawings of the actinomycotic abscess of the liver showing approximate size and location. After surgical extirpation the patient recovered (case 6).

Physical examination revealed an emaciated patient with pronounced pallor and weakness. A large incisional hernia was present at the site of the right rectus incision. A single draining sinus was present in the upper part of the wound.

His hemoglobin was 5.0 Gm. per hundred cubic centimeters, with a normal leukocyte count. Sedimentation rate was 140 mm. per hour (Westergren). Results of repeated smears of the sinus tract and sputum examinations were negative. Roentgengrams of the chest revealed a small density at the right lung base. Roentgenologic studies of the colon revealed no abnormalities.

His temperature reached up to 104 F. daily, and there were some episodes of productive coughing. Nine preoperative transfusions totaling 4,000 cc. of blood were given.

Twelve days after admission the patient underwent a celiotomy. The old right rectus scar, including the sinus tract, was excised. The sinus tract was dissected down to the region between the left lobe of the liver and the diaphragm. A firm mass, the size of a baseball, was palpable in the left lobe of the liver (fig. 2). Results of routine examination of the abdominal contents were otherwise negative. The tumor in the liver was elevated slightly above the surface, but was embedded

in apparently normal hepatic tissue. It was removed by blunt dissection, but a small portion of the base remained. There was moderate venous bleeding. The large defect in the liver was packed with two large gauze packs and its edges secured to the peritoneal edges of the abdominal wound, marsupializing the hepatic defect. The lower end of the incision was closed with interrupted fine silk sutures.

The tumor, after its removal, measured 7 by 5 by 4 cm. and was surrounded by apparently normal hepatic tissue except at the base. There was an outer shell 1 cm. thick, consisting of brownish tissue. The interior presented a honeycombed appearance (fig. 3) with a large number of yellowish green granules, typical of sulfur granules, about 1 to 2 mm. in diameter. Creamy yellow pus could be expressed on slight pressure.

Smears from crushed granules showed branching gram-positive threads with clubbed ends. Examination of a crushed granule in potassium hydroxide showed a

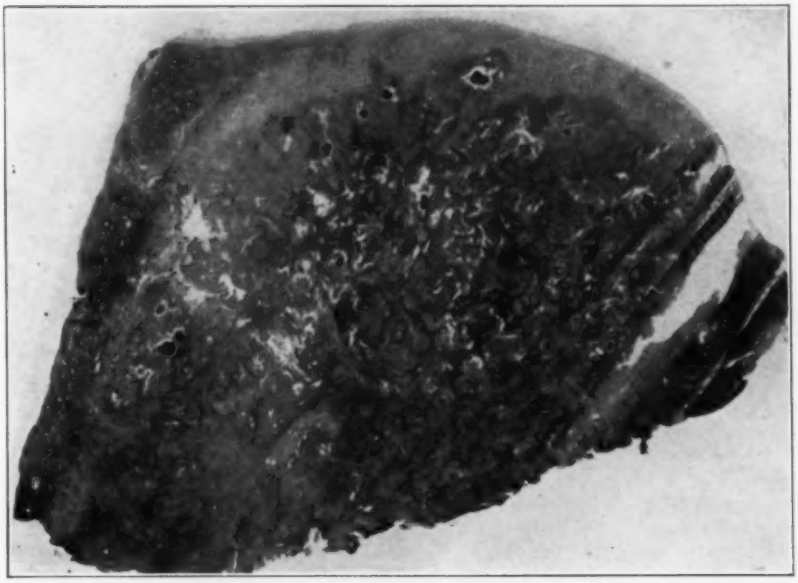

Fig. 3.—Cut section of an actinomycotic abscess of the liver after fixation in formaldehyde (case 6).

typical picture of Actinomyces. Paraffin sections showed numerous small closely packed abscesses which had completely destroyed the hepatic tissue and in which many colonies of Actinomyces were seen (fig. 4). The pus contained many typical Actinomyces grains. Culture of the exudate on thioglycolate broth showed a good growth of Actinomyces.

The packing was removed from the liver on the fourth postoperative day, and treatment with penicillin, 400,000 units daily, was started, until a total of 9,000,000 units had been given. Seventy grams of sulfadiazine over a two week period were also given. The hepatic wound was repacked daily with zinc peroxide paste. Actinomyces were seen in the sputum for the first time on the fourth postoperative day, but were not seen after the eighteenth postoperative day. The patient was afebrile and without cough after the first postoperative week. He was discharged

thirty days after operation, at which time he was decidedly improved, having gained 25 pounds (11 Kg.) in weight. The cavity in the liver still held 70 cc. at the time of discharge.

The patient was readmitted six weeks later for study and another course of penicillin. There was a pinpoint fistula still remaining, with drainage of clear bile. He had continued to gain weight, and the sedimentation rate had dropped to 64 mm. per hour. He was observed for nine days, during which time he received 1,200,000 units of penicillin and 62 Gm. of sulfadiazine. The fistula closed four months after operation.

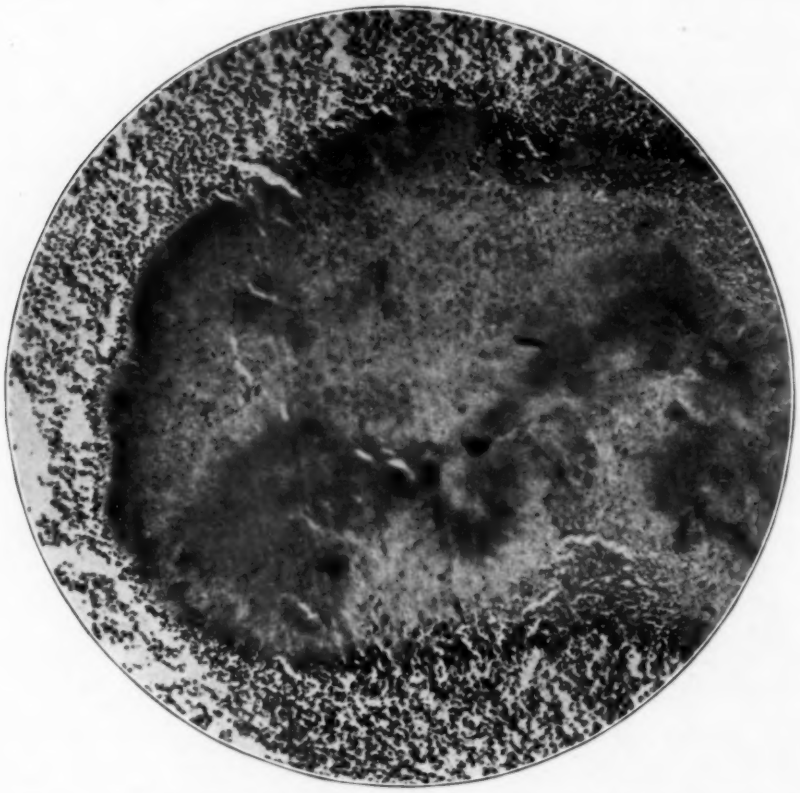

Fig. 4.—Typical colony of Actinomyces from an abscess of the liver (case 6).

The patient was readmitted October 19, six months after removal of the abscess from the liver, with a history of episodes of productive cough. His weight had remained constant, and he had no other complaints. He was afebrile. Roentgenograms revealed a density at the right lung base anteriorly. The sedimentation rate was 70 mm. in one hour. Results of repeated examinations of sputum for Actinomyces were negative. A diagnosis of a subphrenic collection of fluid was made (fig. 5). With the same approach, celiotomy was again performed. The left lobe of the liver was inspected, and there was no evident pathologic condition present. Two biopsies were taken from the site of the previous abscess in the liver, but the sections showed only fibrosing hepatitis. A fistulous tract was then found running through

the diaphragm anteriorly between the right and left lobes of the liver. The opening in the diaphragm was enlarged and approximately 300 cc. of odorless greenish yellow exudate aspirated. The abscess cavity at the cardiophrenic angle was directly adjacent to the mediastinum on the right and anteriorly. A rubber tissue drain was then inserted into the cavity and brought out through the diaphragm and abdominal incision. Smears and cultures of the exudate were negative for pathogenic organisms. The patient received 3,000,000 units of penicillin post-operatively. Drainage from the wound stopped three weeks after operation, and the wound healed.

After his discharge, his course was one of rapid improvement and he returned to his work as a farmer. Oct. 1, 1947, nineteen months after removal of the actinomycotic abscess from the liver and twelve months after the last operation,

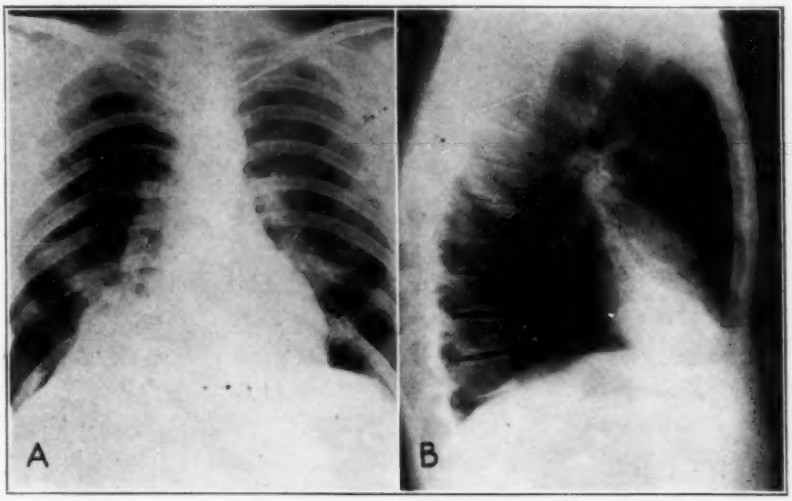

Fig. 5.—*A*, intrathoracic collection of fluid at the right cardiophrenic angle. Though no Actinomyces were identified in this fluid, the patient had previously had the fungus identified in his sputum. *B*, lateral view, showing the intrathoracic collection of fluid. A roentgenogram of the chest taken four weeks later showed no abnormalities (case 6).

results of his examination were entirely negative. He was asymptomatic. Weight, sedimentation rate, hemoglobin and a roentgenogram of the chest were all normal.

Actinomycosis of the liver is an extremely grave condition.[22] Cope [5] stated that were it not for 1 survival reported to him by Gordon-Taylor, he would refer to it as an invariably fatal disease. To our knowledge, Gordon-Taylor's case and our case (case 6) are the only reports of survival of actinomycotic abscess of the liver.

Most cases of hepatic involvement are discovered only at autopsy and represent only a part of a generally disseminated disease.[1c] More

22. (*a*) Dobson and Cutting.[16] (*b*) Robson.[1c] (*c*) Dorling, G. C., and Eckbott, N. L.: Chemotherapy of Abdominal Actinomycosis, Lancet **2**:707 (Dec. 7) 1940.

localized involvement, as in case 6, suggests (*a*) transmission from the stomach and duodenum to the liver via the gastric or portal veins [3b] or (*b*) involvement by direct extension following the escape of the organism from the gastrointestinal tract. In the case reported herein the onset of the illness, obviously started by perforation of a gastric ulcer, makes the latter suggestion more tenable.

Though most authors agree that mycotic fungi in the stomach and duodenum do not cause ulceration,[23] experimental [24] and clinical [25] evidence supports the contention (*a*) that fungi are present in gastric and duodenal ulcerations, (*b*) that chronicity of the ulcerations is probably promoted by their presence and (*c*) that the same organisms, after escape from the gastrointestinal tract, are capable of resuming their more pathogenic attributes.

Actinomycosis primary in the gastric wall is rather rare. Blain [26] first reported a proved case in 1933, and others [27] have since reported similar cases. Though conclusive evidence is lacking, case 5 may conceivably be interpreted as an example of this disease.

CHEMOTHERAPY IN ACTINOMYCOSIS OF THE THORACIC AND ABDOMINAL VISCERA

The influence exerted by treatment with the sulfonamide drugs and penicillin in the control of this infection has been the subject of considerable investigation. In vitro experiments have yielded discouraging results. Keeney, Ajello and Lankford [28] observed: ". . . the inhibiting effect of the sulfonamides on the growth of Actinomycosis bovis is not spectacular and conservatism should be displayed in regard to expectancy of cure from their use in the treatment of human actinomycosis." The same authors were more pessimistic regarding the use of penicillin and reported that only in concentrations rarely achieved clinically is the organism inhibited by this antibiotic. In smaller doses they observed that the organism was actually stimulated and concluded: ". . . the use of penicillin in superficial and deep mycotic infections

23. Shearburn, W.: Actinomycosis of the Stomach and Duodenum, Surgery **14**:38 (July) 1943.

24. Askanazy, M., cited by Singer.[25]

25. Singer, H. A.: Mycotic Gastritis, Arch. Int. Med. **40**:873 (Dec.) 1927.

26. Blain, A. W.: Primary Actinomycosis of the Stomach, J. A. M. A. **100**: 168 (Jan. 21) 1933.

27. Rabinowitz, L.: Ulceration of the Duodenum from Actinomycotic Infections, New England J. Med. **209**:236 (Aug. 3) 1933. Wheeler, W. I. DeC.: A Case of Actinomycotic Ulceration of Duodenum and Jejunum, Brit. J. Surg. **15**:430 (Jan.) 1928. Shearburn.[23]

28. Keeney, E. L.; Ajello, L., and Lankford, E.: Studies on Common Pathogenic Fungi in an Actinomyces Bovis, Bull. Johns Hopkins Hosp. **75**:393 (Dec.) 1944.

is unwarranted and contraindicated." Fisher,[29] however, found two strains of A. bovis sensitive to the action of penicillin. Cutting and Gebhardt[30] observed all the sulfonamide drugs to inhibit the growth of two strains of Actinomyces hominis, but sulfathiazole and sulfadiazine were definitely more effective in the same concentrations than sulfanilamide. Dobson and Cutting[16] observed that both sulfadiazine and penicillin inhibited three strains of Actinomyces, but were actually less effective when used together than when used separately. Sulfadiazine seemed to be more effective unless very high concentrations of penicillin were used.

Clinically, most reports on the use of these agents are encouraging. Walker,[31] in 1938, reported the first successful use of sulfanilamide in a soldier with appendical actinomycosis. In 1939, Miller and Fell[32] reported a similar case, in which improvement followed the administration of sulfanilamide. The use of sulfanilamide in cervicofacial cases was reported at the same time by Sudler and Johnson[33] and MacCharles and Kippen.[34] Other reports of the successful use of sulfonamide drugs in cases of abdominal and thoracic disease quickly followed.[35]

The use of penicillin was first reported by Herrell[36] in 1944. He reported 4 cases, only 1 of which was an abdominal case, and it was complicated by a carcinoma of the colon. Of 3 cervicofacial cases, treatment in 2 was listed as satisfactory and in 1 as a failure. Later reports[37] were more encouraging, particularly in the use of penicillin in thoracic cases. It is generally agreed, however, that in order for treatment with the sulfonamide drugs or penicillin to be effective large doses must be

29. Fisher, A. M.: The Anti-Bacterial Properties of Crude Penicillin, Bull. Johns Hopkins Hosp. **73**:343 (Nov.) 1943.

30. Cutting, W. C., and Gebhardt, L. D.: Inhibitory Effects of Sulfonamides on Cultures of Actinomyces Hominis, Science **94**:568 (Dec. 12) 1941.

31. Walker, O.: Sulfanilamide in the Treatment of Actinomycosis, Lancet **1**:1219 (May 28) 1937.

32. Miller, E. M., and Fell, E. H.: Sulfanilamide Therapy in Actinomycosis, J. A. M. A. **112**:731 (Feb. 25) 1939.

33. Sudler, M. T., and Johnson, C. B.: Treatment of Actinomycosis with Sulfanilamide: Report of Two Cases, J. Kansas M. Soc. **40**:330 (Aug.) 1939.

34. MacCharles, M. R., and Kippen, J. W.: Three Cases of Actinomycosis Treated with Sulphanilamide, Canad. M. A. J. **41**:490 (Nov.) 1939.

35. Ogilvie, W. H.: Abdominal Actinomycosis Treated with Sulphapyridine, Brit. M. J. **2**:254 (Aug. 24) 1940. Christopher, F., and Karabin, J. E.: Abdominal Actinomycosis: Recovery Following Surgical Treatment and the Use of Zinc Peroxide and Sulfanilamide, Am. J. Surg. **50**:371 (Nov.) 1940. Dorling and Eckbott.[22c] Dobson, Holman and Cutting.[8a] Wilkinson.[13] Ladd and Bill.[14]

36. Herrell, W. E.: The Clinical Use of Penicillin, J. A. M. A. **124**:622 (March 4) 1944.

37. Walker and Hamilton.[3c] Jones and Brownell.[15] Dobson and Cutting.[16]

employed. Of cases so far reported in which penicillin was used as the primary therapeutic agent, results in few were listed as satisfactory when less than 6,000,000 units were given.

The evaluation of chemotherapeutic measures, with particular reference to sulfonamide drugs and penicillin, is difficult, and many years will probably elapse before an accurate appraisal can be made. Meleney [38] in a review of this subject points out some of these difficulties. Among the more important are (*a*) the extent and location of the infection, (*b*) duration of the illness, (*c*) surgical procedures and treatment before admission, (*d*) mixture of organisms and (*e*) the problem of local and general immunity. Despite the nonuniformity of these points in cases reported, there can remain little doubt in the mind of one familiar with the literature of this subject that a definite advance has been made with the addition of sulfonamide drugs and penicillin to the surgical armamentarium. Measured by reported survivors, the combination of fundamental surgical principles and adequate doses of sulfonamide drugs and penicillin outdistances all competitors. It has, in fact, reduced this disease from one which only a few years ago was frequently reported as "uniformly fatal or nearly so" to one which, although still serious, now offers considerable hope of recovery and good health to those afflicted.

SUMMARY

Six cases of actinomycosis involving abdominal or thoracic viscera are reported. One case is believed to be the second reported in which the patient survived actinomycotic abscess of the liver. The use of sulfonamide drugs and penicillin in adequate amounts, in addition to recognized surgical principles, is a definte contribution in the treatment of this disease.

38. Meleney, F. L.: The Difficulty of Evaluating Drug Treatment in Surgical Infections, J. A. M. A. **124**:1021 (April 8) 1944.

PREVENTION AND TREATMENT OF WOUND DEHISCENCE

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ST. LOUIS

SEVERAL years ago Norris [1] stated, "the elimination of postoperative wound dehiscence is entirely within the jurisdiction of the operating surgeon," yet the occurrence of this surgical catastrophe remains uncomfortably constant. To say that this major complication of abdominal surgical treatment is shocking to the surgeon and the patient alike is a decided understatement.

The term "dehiscence," from the verb, "dehiscere," to gape, is graphic and descriptive. As used throughout this paper, it applies to that condition in which any portion of the contents of the peritoneal cavity is extruded from that cavity and presents itself in the operative wound. Within the past decade several excellent statistical studies [2] of wound disruption, with purposeful discussions concerning corrective measures, have been made and are available in the literature.

INCIDENCE AND MORTALITY

The incidence of this surgical complication and its mortality rate have been rather uniform for the past fifteen years, as shown in table 1. These statistics become all the more forceful and thought provoking when one considers that in these series the majority of the closures were carried out using the two general and prevalent types of sutures—the absorbable sutures, surgical gut from two institutions, and the nonabsorbable sutures of silk from the other two hospitals.

FACTORS

Many authors emphasize the factors that are present in the cases of potential wound dehiscence. Elaborate analyses of the laparotomies

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Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 21, 1948.

From the Department of Surgery, Washington University School of Medicine and The Medical Center, St. Louis.

1. Norris, J. D.: Surgery **5**:775, 1939.

2. Jenkins, H. P.: Surg., Gynec. & Obst. **64**:648, 1937. Singleton, A. O., and Blocker, T. G.: Problem of Disruption of Abdominal Wounds and Postoperative Hernia: Review of 9,000 Consecutive Abdominal Incisions, J. A. M. A. **112**:122 (Jan. 14) 1939. Tashiro, S.: Surg., Gynec. & Obst. **78**:487, 1944.

to show the site of the incision, the type of operation performed, the presence and absence of malignant growth, the presence of actual or potential infection and the type of suture material used in the closure of the abdomen are available in the reviews previously referred to; they have been properly analyzed and will not be repeated. Indeed, both Dr. Samuel C. Harvey and Dr. Allen O. Whipple pointed out many years ago, while discussing this specific problem before the members of the American Surgical Association, that the emphasis from an analytic point of view must rest solely on those cases in which wound disruption occurred, a fact that Glenn and Moore [3] have developed in their survey. Specific information concerning these cases, and these alone, is pertinent.

TABLE 1.—*Data on Wound Disruption from Four Institutions*

	New York Hospital	Cleveland Clinic	Mt. Sinai Hospital	Barnes Hospital
Laparotomies	6,417	4,154	2,750	5,781
Total eviscerations	43	44	26	47
Incidence (percentage)	0.66	1.05	0.9	0.82
Deaths	14	15	7	16
Mortality rate (percentage)	30.2	34	29	34

TABLE 2.—*Factors in Wound Dehiscence*

Predisposing causes
- I. Debility of the aged
- II. Presence of jaundice
- III. Impairment of blood supply from arteriosclerosis and diabetes
- IV. Cachexia of malignant conditions

Exciting causes
- I. Respiratory distress
- II. Peritoneal irritation
- III. Presence of increased intra-abdominal tension

Table 2 lists the factors which enter the problem as outlined by White.[4] Such a division into "predisposing causes" and "existing causes" is helpful from the point of view of case analysis and of preoperative preparation. In the light of our present knowledge of common methods to improve or eliminate many of these factors, many of these phases will not be developed at this time.

PREVENTION

All are agreed that the patients with advanced malignant conditions make up the greatest group of those who undergo wound dehiscence. The second most commonly afflicted type of patient is the stocky hyper-

3. Glenn, F., and Moore, S. W.: Surg., Gynec. & Obst. **72**:1041, 1941.
4. White, W. C.: Ann. Surg. **99**:34, 1934.

sthenic person with a short thick neck and a corresponding torso, who, because of his powerful abdominal muscles, is able to increase intra-abdominal tension far above the normal and all out of proportion to the tensile strength of the healing process of the abdominal wound. A third group includes patients with debilitating diseases with hypoproteinemia.[5] The relationship of vitamin C to wound healing is interesting both from an experimental and a clinical point of view. Lund and his co-workers [6] showed that vitamin C is essential to the formation of collagen. Wolfer and Hoebel [7] emphasized the importance of the determination of vitamin C and recommended the administration of 1,000 mg. a day until tests prove the normal requirements to be satisfactory. The significance of anemia and hypoproteinemia is now appreciated. However, recent studies are available which would tend to show that the tissue protein values are not clearly reflected in the blood proteins, which may account for some of the wound disruptions in patients that have reportedly normal serum proteins with a satisfactory albumin-globulin ratio.

TABLE 3.—*Prevention of Wound Dehiscence*

I.	Correction of hypoproteinemia
II.	Replacement of hemoglobin or red blood cell loss or deficiency
III.	Adequate relaxation from anesthesia
IV.	Selection of the incision for proper exposure
V.	The closure
	(*a*) The principles
	(*b*) The stainless steel suture
VI.	Prevention of increased intra-abdominal tension
VII.	Role of early ambulation

METHOD OF CLOSURE

Whether the causative factor lies in the role of protein and vitamin C deficiencies in the cachectic patient, the imperfect and incomplete closure of the peritoneum in the normal person or the postoperative pulmonary or peritoneal complications in either type, the object of this communication is to present again a method of closure of abdominal wounds in selected patients, most of whom are potential candidates for wound disruption, that has improved the incidence of wound dehiscence in the Barnes Hospital (table 3). The method that is used is similar to that fully described by Jones [8] and associates—the utilization of alloy

5. Thompson, W. D.; Ravdin, I. S.; Rhoads, J. D., and Frank, I. L.: Use of Lyophile Plasma in Correction of Hypoproteinemia and Prevention of Wound Disruption, Arch. Surg. **36**:508 (March) 1938.

6. Crandon, J. H., and Lund, C. C.: New England J. Med. **222**:748, 1940. Lund, C. C.; Crandon, J. H., and Dill, D. B.: ibid. **223**:353, 1940.

7. Wolfer, J. A., and Hoebel, F. C.: Surg., Gynec. & Obst. **69**:745, 1939.

8. Jones, T. C.; Newell, E. T., and Brubacker, R. E.: Surg., Gynec. & Obst. **72**:1056, 1941.

steel wire in the closure of abdominal wounds. Jones gave full credit to the introduction of the particular stitch under consideration to Dr. Louis Smead of Toledo, Ohio (fig. 1).

At the time of the closure, the wire suture, no. 30 stainless steel, on a medium-sized round needle, is introduced through the anterior sheath of the rectus muscle and passed through the intervening muscle, its posterior sheath and the peritoneum in the same plane. The needle and suture are then brought up through the opposite side of the incision in a similar fashion, including peritoneum, the posterior sheath, the rectum abdominis muscle and the anterior sheath of the rectus

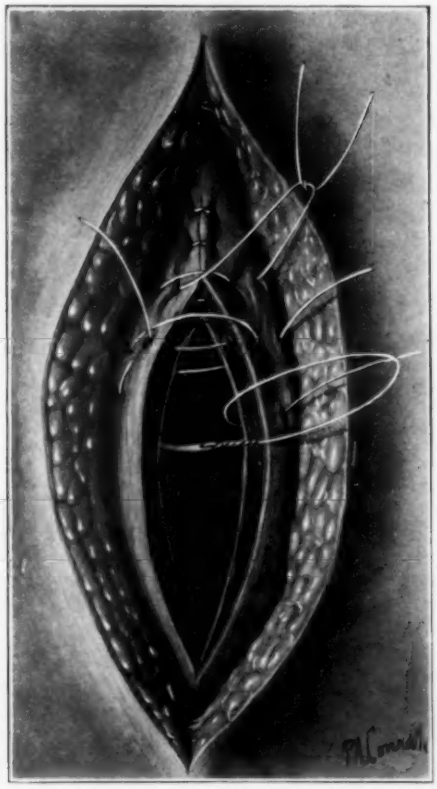

Fig. 1.—Drawing of the type of stitch used.

muscle. These two "bites" are placed about 1 cm. from the edge of the incision. The second limb of the stitch consists of a loop to approximate the two leaves of the anterior sheath of the rectus muscle. The two limbs of the sutures are drawn snugly and four knots placed in the usual fashion. The wires are cut flush with a hemostat placed above the knot, which is then rotated to invert the cut ends of the stainless steel wire suture. Three running sutures of no. 30 stainless steel wire are then placed in the subcutaneous tissues, as shown in figure 2, to obliterate the dead space and to approximate the skin. This method of closure has been popularized by Dr. Frederick Coller and his co-workers at Ann Arbor, Mich., for a good many

years. The use of alloy or "stainless steel wire," from a historical point of view,[9] dates back not too many years and is amply covered in the literature. Most important of all, such sutures are now available and are relatively inexpensive.

An analysis of the 1,701 cases in which laparotomies were performed in Barnes Hospital during the year of 1947 reveals the fallacy of figures and statistics (table 4)and the need for a careful analysis of the individual cases. In the 11 cases in which there was wound dehiscence, there were no closures with stainless steel wire and in all there were one or more of the primary factors present in cases of potential wound dehiscence. There were 308 cases in which a closure with stainless steel wire was carried out during the year of 1947 by seven different surgeons. The reduction of the incidence of wound dehiscence after the adoption of this method of closure in two other hospitals,[10] as shown in table 5, is interesting, although only a few cases are reported. These figures would add some credence to

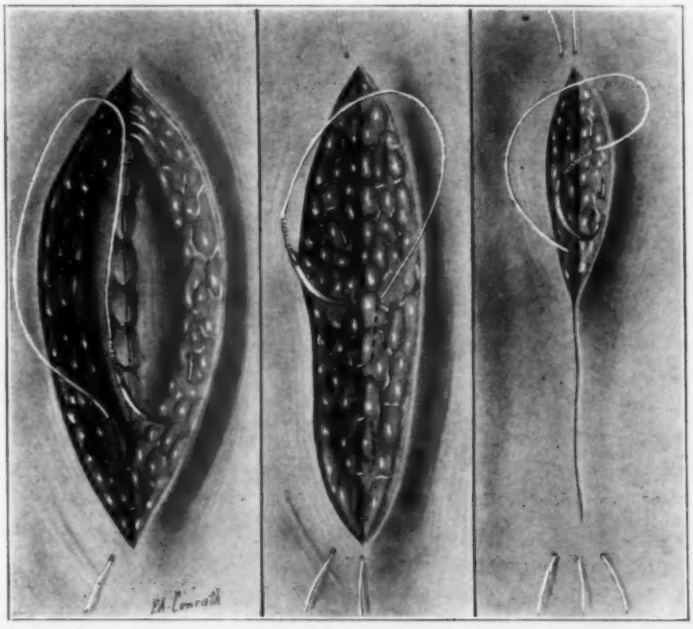

Fig. 2.—Drawing of the type of closure popularized by Dr. Frederick Coller.

the report of efficacy of this method of closure, but because of the relatively few cases an additional test of time must be carried out and many more cases reviewed before further deductions can be drawn.

EXPERIMENTAL WORK

The role of increased intra-abdominal tension is often overlooked in the preoperative planning and postoperative care of patients, and yet

9. Babcock, W. W.: Ligatures and Sutures of Alloy Steel Wire, J. A. M. A. **102**:1756 (May 26) 1934. Kaufman, L. P.; Johnson, W. W., and Lesser, A.: Surg., Gynec. & Obst. **69**:684, 1939. Kraissl, C., Jr.: ibid. **62**:417, 1936.

10. Wiley, H. M., and Sugerbaker, E. D.: Surg., Gynec. & Obst. **85**:81, 1947.

this is the immediate physical effect produced by coughing and vomiting, the two common factors in or exciting causes of wound dehiscence. Experimental work was carried out in the laboratories of the Department of Surgery, Washington University School of Medicine, several years ago on dogs, in which increased intraperitoneal pressure was created and maintained.

A series of dogs received relatively small doses of morphine compound breathed through a modified Benedict spirometer, and their oxygen consumption was recorded. At appropriate intervals samples of venous blood from the right side of the heart and arterial blood from the femoral artery were taken and the oxygen content determined by Van Slyke's method. Using Fick's formula, the cardiac output of the normal resting animal was calculated.

TABLE 4.—*Analysis of Laparotomies at Barnes Hospital, 1947*

Total number of laparotomies	1,701
Total eviscerations *	11
Carcinomas	4
Myomas	2
Duodenal ulcer (gastric resection)	2
Familial jaundice (splenectomy)	1
Appendical abscess (drainage)	1
Volvolus of sigmoid (reduction)	1

* None of the closures were done with stainless steel wire.

TABLE 5.—*Improvement After the Use of Stainless Steel Vertical Mattress Sutures*

	Total Number of Cases
Wiley and Sugarbaker (Surg. Gynec. & Obst. **62**: 417, 1936)	
Malignant conditions	86
Dehiscence	0
Jones, Newel and Brubaker (Surg. Gynec. & Obst. **17**: 1056, 1941)	
Malignant conditions	116
Dehiscence	0

The intraperitoneal pressure was then increased by different methods. In one series of animals, air or isotonic sodium chloride solution was injected intraperitoneally and the intraperitoneal pressure thus elevated rapidly, but temporarily. In a second series, sterile liquid petrolatum was injected into the abdomen, which gave a slow but permanent elevation of the intraperitoneal pressure. With this latter method it was not possible to influence the cardiac output in the face of chronic increased intraperitoneal tension, even when the intraperitoneal pressure was elevated as high as 300 mm. of mercury. This seemed most unusual in view of the elevation of the pulse rate and the definite shortening of the respiratory excursions with their increase in rate, yet a chronic increase in intraperitoneal pressure did not endanger their lives.

A group of dogs was anesthetized with "amytal" (5-isoamyl-5-ethylbarbituric acid), and, after a normal blood pressure tracing and cardiac rate had been recorded, a cannula was inserted through the abdominal wall and air introduced. The rapid but controlled rise in intraperitoneal pressure was recorded, and the effects which were constant were recorded and noted.

1. As long as the intraperitoneal pressure remained less than the systolic blood pressure there was only a slight increase in pulse rate with concomitant elevations of the blood pressure and an increase in respiratory rate, all of which returned to normal limits in a relatively short interval, apparently the result of the compensatory action.

2. If the intraperitoneal pressure was caused to exceed the systolic blood pressure by an average of 50 mm. of mercury there was an immediate increase in blood pressure, pulse rate and respiratory rate which was shortly followed by a sharp drop in blood pressure, which continued to fall until the intraperitoneal pressure was decreased, at which time it returned to normal. The pulse rate increased throughout, as long as the intraperitoneal pressure remained above the systolic pressure. If the intraperitoneal pressure exceeded the systolic pressure for a period of three hours, the animals uniformly underwent irreversible reactions and died.

3. Autopsies performed immediately after death on animals which had been subjected to long periods of increased intraperitoneal pressure revealed two constant observations: (*a*) The splanchnic vessels were pale and collapsed, and the viscera obviously contained only a relatively small amount of blood, and (*b*) the diaphragm was elevated as far as the second interspaces because of mechanical displacement of the lungs, which were collapsed and showed some acute pulmonary edema.

From this experimental work it becomes increasingly evident that this factor of increased intra-abdominal tension as produced by coughing and vomiting must be kept under control at all times as it may play a major role in the mortality rate in cases of wound dehiscence.

DIAGNOSIS

The prevention of wound dehiscence differs from the management of wound dehiscence just as elective surgical treatment differs from emergency surgical treatment. The primary aim in the management of wound dehiscence is to save a life, and the correction of a pathologic condition must be of secondary importance.

An early diagnosis is imperative. A common sign is the presence of odorless pink-stained fluid from the suture line or on the dressings, and a common symptom is the persistence of nausea, vomiting, hiccups or other manifestations of peritoneal irritation without clinical justification. A careful examination of the wound with an exploration of the subcutaneous tissues after the removal of cutaneous and subcutaneous sutures must be carried out in every case of suspected wound dehiscence. This can be done without anesthesia in a painless fashion in the patient's room. In spite of major disruptions, patients are frequently afebrile, have a sense of well-being and present a white blood cell count that may not reflect the peritoneal irritation. The positive observations in cases of wound dehiscence range from a relatively small protrusion of omentum through the suture line of the peritoneum into the subcutaneous tissues to the presence of loops of intestine and other viscera on the abdominal wall—actual evisceration.

MANAGEMENT

Once the diagnosis has been established, the subsequent treatment is emergency in type and imperative in nature (table 6). As has been pointed out by others, many of these patients have been or are suffering from constitutional alterations that have led to this surgical catastrophe

TABLE 6.—*Factors in Management of Wound Dehiscence*

I.	Emergency surgical treatment
II.	Transfusion of whole blood
III.	Anesthetic of choice
IV.	"Through and through" closure in the operating theater
V.	Postoperative care
	(*a*) Control of peritoneal irritation
	(*b*) Control of respiratory complications

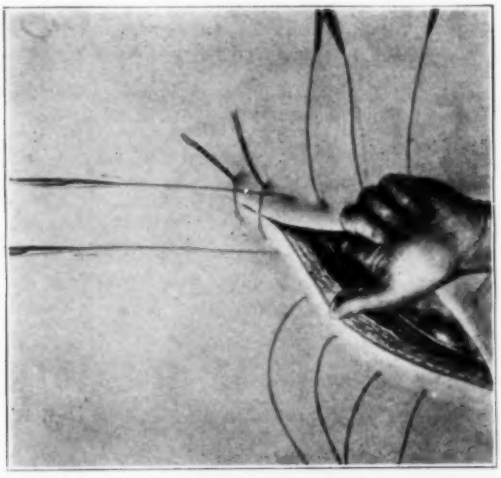

Fig. 3.—"Through and through" sutures placed through all layers of the abdominal wall about 2 cm. apart.

and should receive immediate attention. The operative procedure should be carried out in the operating theater with adequate instruments and an operating team. The ideal anesthetic for the correction of wound dehiscence is "pentothal sodium" (sodium 5-ethyl-5-[1-methylbutyl] thiobarbiturate) given intravenously, although local infiltration has been frequently used. The administration of the anesthetic should not be started until after the patient's abdomen has been prepared and draped and whole blood is running in a vein in satisfactory fashion. "Through and through" sutures are quickly placed through all layers of the abdominal wall about 2 cm. apart. Stainless steel wire sutures (no. 30) are placed after the fashion illustrated by Reid, Zinninger and Merrill (fig. 3). There has perhaps not been enough emphasis placed on the

fact that the introduction of any additional sutures will trap infection, permit the accumulation of serum and defeat the purpose of this method of closure. The management of wound dehiscence by "packing," strapping or tamponade is mentioned only to condemn it.

In selected cases, patients are encouraged to participate in a program of early ambulation. Surgical judgment based on experience must rule supreme at this level.

COMMENT

The application of self-evident surgical principles experimentally shown by Harvey and Howes concerning the accurate approximation in layer closure and the need for hemostasis and the use of fine suture material as emphasized by Whipple should again be mentioned because of their paramount importance in the closure of any abdominal wound. The most lasting of surgical tenets must be carried over into this field of prevention. The only apparent break is the introduction of a suture material with the tensile strength of stainless steel wire—material

TABLE 7.—*Selection of Patients for Stainless Steel Closure*

I.	All patients that have an acute intra-abdominal infection
II.	All patients with malignant conditions
III.	All patients with chronic disease when there is a possibility of delayed wound healing
IV.	All obese and elderly patients who should practice early ambulation

that has a tensile strength far greater than that of the tissues. Our school of thought is firmly convinced of the principles long ago introduced by Harvey, Howes and others that the "tissues hold the sutures . . . the sutures do not hold the tissues," but in debilitated patients the tissues will not hold any sutures unless one takes advantage of their bulk and incorporates it into a loosely tied vertical mattress stitch or one similar—one in which the tissues again are actually capable of holding the sutures. Perhaps silk or cotton would suffice, but the strength of this stainless steel wire, which even Dr. Halsted stated to be ideal from the point of view of its physical properties, is most comforting to surgeon and patient alike, reduces mortality and permits early ambulation when indicated.

It must be self evident that most surgeons would prefer a layer closure in laparotomies which unquestionably would give the maximum results if the tissues they were dealing with were normal. It is only when one is dealing with abnormal tissues that it might be advisable to use the "buttressing effect" of the vertical mattress suture as described in this presentation (table 7, fig. 10).

SUMMARY AND CONCLUSIONS

In spite of the present day conception of the various factors influencing wound dehiscence, this surgical complication occurs, and its rate is remarkably constant in the "layer" type of closure regardless of the suture material used. A method of closure in cases of potential dehiscence with stainless steel wire has proved satisfactory in the hands of some of the surgeons at the Washington University School of Medicine and The Medical Center, St. Louis. In certain potential cases of wound dehiscence, routine closure with stainless steel wire might lower the over-all incidence with its accompanying mortality rate. These would include (*a*) all patients with an acute massive intra-abdominal infection, (*b*) all patients with intra-abdominal malignant conditions, (*c*) all patients with chronic disease when there is a possibility of delayed wound healing and (*d*) all obese and elderly patients who should practice early ambulation. The time to think of and to prepare for possible wound dehiscence is prior to operation. The role of increased intra-abdominal pressure is emphasized, based on some original experiments. Once wound dehiscence has occurred, early diagnosis and evaluation of the acuteness of the surgical emergency are important.

DISCUSSION

DR. HENRY K. RANSOM, Ann Arbor, Mich.: I wish to discuss only one phase of Dr. Walton's paper, i. e., the use of alloy steel wire in the closure of laparotomy wounds. In our surgical clinic at University Hospital, stainless steel wire has been used for closure since 1937. When vertical incisions were commonly used a modification of the figure of eight stitch as advocated by Jones was found satisfactory. With this the peritoneum and fascia are included in one stitch. More recently transverse incisions have been employed in practically all of our abdominal surgical cases. Here the peritoneum is closed with a running stitch of surgical gut or with interrupted sutures of no. 32 wire and a layer closure of the overlying muscles and fascia obtained by the use of no. 30 or 32 wire. Experimentally, wire has been shown to excite a minimal amount of tissue reaction, and clinical experience with it has been most satisfactory. Even though wound sepsis supervenes, complete healing almost invariably takes place without the extrusion of sutures. Rarely sinus formation has been observed when a wire suture has served as the offending foreign body. This complication is much less frequent than when either silk or cotton sutures are used. Experience has shown that wire sutures should be firmly and accurately tied and the ends cut very short. In thin persons it is advisable that the knot be buried, in order to prevent tenderness over the sutures. The skin and subcutaneous fat are closed with a continuous wire suture placed in the manner of a Cushing right angle suture, with the ends left long for subsequent removal. If the subcutaneous fat is abundant, two or more tiers may be used. Such sutures avoid ischemia due to compression of tissues and leave the wound free of foreign material. My associates and I believe that the wire closure of wounds is superior to any other method which has been used.

DOUBLE AORTIC ARCH

Report of Two Cases

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AND
STANLEY GIBSON, M.D.
CHICAGO
AND
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SALT LAKE CITY

NOTHING stimulates more interest in a hitherto hopeless condition than the discovery of an effective means of therapeusis. This has been especially true recently in the entire field of congenital cardiac disease. For about two hundred years pathologists had known of double aortic arch, a rather rare abnormality, and physicians had correlated the postmortem observations with the rather classic clinical history. Case reports were occasionally published but read by few, because "nothing could be done anyway" for the unfortunate children. Then, in 1945, Gross [1] published the first report of a child with a double aortic arch successfully treated surgically. Now every pediatrician is on the lookout for such cases.

The clinical picture of this anomaly is rather characteristic. Laryngeal stridor and difficult respiration are usually the first symptoms which indicate to the mother that all is not well with her child. These symptoms appear shortly after birth, may be relatively mild or severe, are often intermittent and at times vary with the position in which the infant is placed. Respirations are usually rapid and noisy, and even during sleep breathing is labored. Asthma-like wheezing can be heard in the chest. Attacks of severe dyspnea are frequently associated with cyanosis and suprasternal retraction. Spells of unconsciousness are not uncommon. Recurrent infections of the upper part of the respiratory tract, bronchitis and pneumonia keep the child in a poor state of health. As the child grows older, a crowing nonproductive cough, like the bark of a sea lion, is characteristic.

Dysphagia is an equally distressing symptom of double aortic arch. At times the feedings are taken eagerly, without any apparent discomfort.

From the Children's Memorial Hospital, Chicago.

Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 22, 1948.

1. Gross, R. E.: Surgical Relief for Tracheal Obstruction from a Vascular Ring, New England J. Med. **233**:586 (Nov. 15) 1945.

Most of the time, however, feeding is a problem. Difficulty in swallowing and regurgitation are likely to set off an attack of coughing, stridor, difficulty in breathing and cyanosis. The infant must often be coaxed to take enough food to supply caloric requirements. In both cases herewith reported, the need to stop feeding and give emergency oxygen was not uncommon.

These symptoms, not unlike those ordinarily ascribed to an enlarged thymus, have prompted a course of roentgen therapy to the thymic region in a number of reported cases. It is not unlikely that many

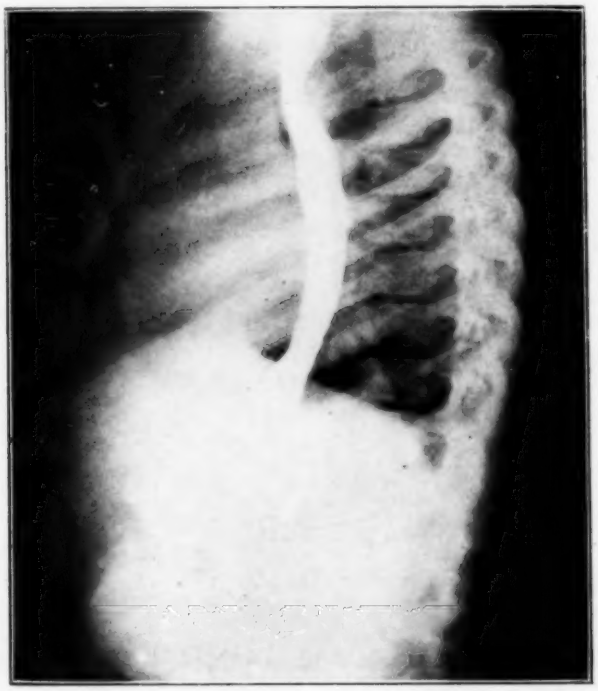

Fig. 1 (case 2).—Lateral roentgenogram showing concavity in esophagus.

infants who have met so-called "thymic death" have had unrecognized anomalies of the aortic arch.

The suspected diagnosis is confirmed by fluoroscopic and roentgen examination. To Dr. E. B. D. Newhauser, quoted by Gross, belongs the credit for detecting the characteristic abnormality roentgenographically. Administration orally of barium sulfate or iodized poppyseed oil will help show a concave defect in the esophagus (fig. 1) produced by pressure of the abnormal vessel. This defect is best seen in the lateral view, but may also be apparent in the anteroposterior view, depending on the course of the abnormal vessel. The size of the filling defect in the esophagus will, of course, depend on the size of the vessel producing

pressure. Bronchoscopic examination with or without instillation of iodized poppyseed oil may show a depression in the trachea just above the carina. In fact, in case 2 in this paper, Dr. Paul Holinger noted such a defect in the trachea in 1941 and suggested that it might be due to anomalies of the large vessels in the mediastinum.

The pathologic aspects of double aortic arch are well described by Gross,[1] Gross and Ware [2] and Gordon.[3] The ascending arch splits into two segments, which encircle the esophagus and trachea and then reunite to form the descending aorta. Normally the left fourth arch persists to form the aorta and its branches. If the right arch also persists, there is a double aortic arch. The left arch is spoken of as the anterior segment and the right arch as the posterior segment. From a teaching standpoint this is confusing. A clearer mental image is obtained if the two segments are referred to according to their position in reference to the trachea and esophagus—anterior or posterior. The anterior limb is usually the smaller and may be only a vestigial remnant. The posterior limb carries most of the blood. Variations in the development of the arch alone occur. Added to these are many possible variations in the origin of the large branches and their relationship to the trachea and the esophagus. It is not uncommon to observe at postmortem examination an unsuspected symptomless double aortic arch. Symptoms will be produced only if the vascular ring, however formed, constricts the enclosed structures.

REPORT OF CASES

CASE 1.—D. Z. (previously reported by Gordon [3]), a white male infant weighing 8 pounds (about 3,629 Gm.), was delivered at St. Mary's Mercy Hospital, Gary, Ind. The infant had been in an oxygen tent after birth but was well until 5 weeks of age, when the mother first noticed noisy and labored breathing, worse during feeding and while the baby was lying prone. The baby was readmitted to this hospital at 7 weeks of age, because of stridor, dysphagia, attacks of cyanosis and aspiration pneumonia. On June 29, 1946, at the age of 4 months, when he weighed 15 pounds (about 6,804 Gm.), the baby was transferred to the Children's Memorial Hospital. With each breath there was inspiratory stridor and suprasternal and supraclavicular retraction. Attacks of cyanosis were severe and at times followed by short periods of unconsciousness. Oxygen for emergency was kept at the bedside all of the time.

Bronchoscopic examination by Dr. Paul Holinger revealed stenosis of the trachea just above the carina.

For fluoroscopic examination of the esophagus a swallow of iodized poppyseed oil was given instead of barium sulfate because of the danger of aspiration. The material was seen to hesitate at the level of the third intercostal space, where an indentation in the posterior wall of the esophagus was momentarily visible. Roentgenograms for a permanent record could not be obtained.

A diagnosis of constricting vascular ring, due most likely to a double aortic arch, was made.

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2. Gross, R. E., and Ware, P. F.: The Surgical Significance of Aortic Arch Anomalies, Surg., Gynec. & Obst. **83**:435 (Oct.) 1946.

3. Gordon, S.: Double Aortic Arch, J. Pediat. **30**:428 (April) 1947.

Operation (July 27, 1946).—Under cyclopropane anesthesia, the left pleural cavity was opened anteriorly through the third interspace. The second and third ribs were cut at the sternal margin. Adequate exposure was obtained with a rib spreader. The mediastinal structures were exposed through a longitudinal incision in the mediastinal pleura lateral to and parallel with the phrenic nerve (fig. 2). The ductus arteriosus was seen to be obliterated. The arch of the aorta appeared normal in size and position. The innominate, left common carotid and left subclavian arteries apparently arose from the aorta in their usual normal positions. There was no evidence of a vascular ring or any other abnormality. The mediastinal pleura was repaired. The lung was reexpanded, and the chest was closed. The ribs were apposed with three sutures of surgical gut encircling adjoining ribs, the second and third ribs were sutured to their sternal margins and the

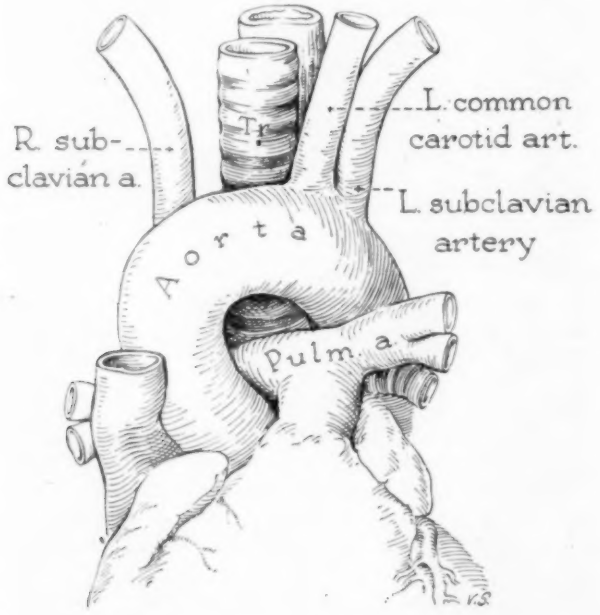

Fig. 2 (case 1).—Observations at operation viewed anteriorly.

muscles sutured with fine running sutures of surgical gut. The child left the operating room in good condition.

Three days after operation the infant had a sudden attack of cyanosis and died.

Postmortem Examination.—Abnormal observations were limited to the arch of the aorta. It was gratifying to learn that the diagnosis of double arch was correct, but disheartening to realize that more extensive surgical exploration would have exposed the constricting vessel, which could easily have been cut (fig. 3). We were deceived by the fact that the anterior segment of the arch was the larger instead of being the smaller, as has been the rule in cases reported to date. From the anterior segment the left subclavian and the left common carotid arteries arose independently. The large vessel on the right, which at operation was poorly visualized but thought to be the innominate artery, proved at postmortem examination to be the right subclavian artery which arose from the posterior segment.

We wrote to Dr. Gross telling him of our catastrophe and the unusual postmortem observations. Two weeks later we received a note of thanks from him for describing our case. He had had a similar one. At operation he had cut a few intercostal vessels, rotated the descending aorta forward and identified and cut the small posterior segment of a double aortic arch. His patient made an uneventful postoperative recovery.

CASE 2.—S. W., a white boy born June 22, 1939, was first admitted to the Children's Memorial Hospital, September 18, because of difficult and crowing respirations which had begun shortly after birth. At times the breathing had been so labored that the infant became cyanotic. Examination revealed stridor, noisy rapid respirations and suprasternal and xiphoid retraction with each breath. He was discharged from the hospital with a diagnosis of congenital laryngeal stridor.

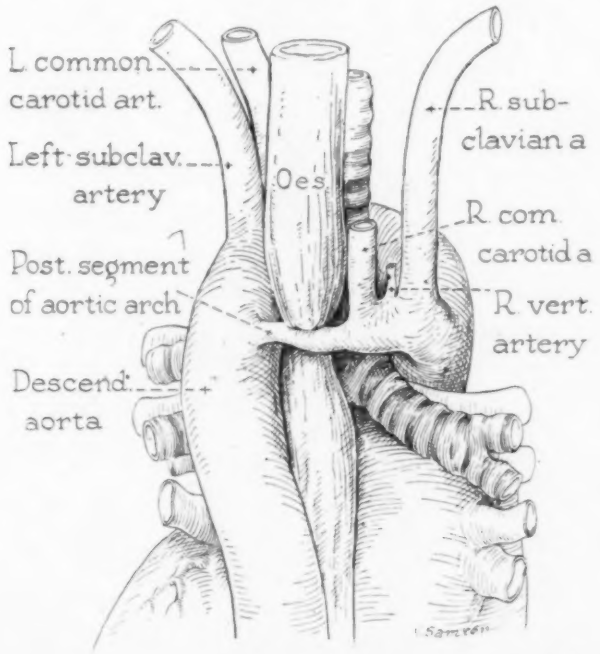

Fig. 3 (case 1).—Observations at postmortem examination. Mediastinal structures viewed posteriorly.

During the next two years he was admitted to the hospital eight times—each time because of stridor, dysphagia and attacks of cyanosis. Each time he was discharged with a diagnosis of congenital obstruction of the larynx. In January 1941, Dr. Paul Holinger examined the baby (then 18 months old) bronchoscopically and suggested that the obstruction of the trachea and esophagus might be due to an anomaly of the great vessels. The significance of this observation was not realized.

During the next five years, the child was actually admitted to the hospital twenty-one times, a number of times with infection of the upper part of the respiratory tract and frequently in an emergency, because of extreme difficulty in breathing and cyanosis. Each time, after a few days of rest and oxygen therapy, he recovered and was discharged. He was then lost to the clinic until his last admission Oct. 18, 1947. In the meantime Gross had published his papers on anomalies

of the aortic arch. This time the diagnosis was made promptly and confirmed by roentgenographic examination (fig. 1).

The patient was now 8 years old and weighed 46 pounds (about 21 Kg.). Stridor and dysphagia had persisted all these years, but had slowly become less troublesome and of less concern to the parents. His cough sounded like the bark of a sea lion. It was very noisy. The child had learned how to swallow small amounts of solid food and wash them down with liquids. He was still handicapped by labored breathing and could walk only short distances.

Operation (Oct. 27, 1947).—Under intratracheal cyclopropane anesthesia, administered by Dr. William O. McQuiston, the chest was opened through a posterolateral incision in the fourth left interspace. The left lung was retracted down-

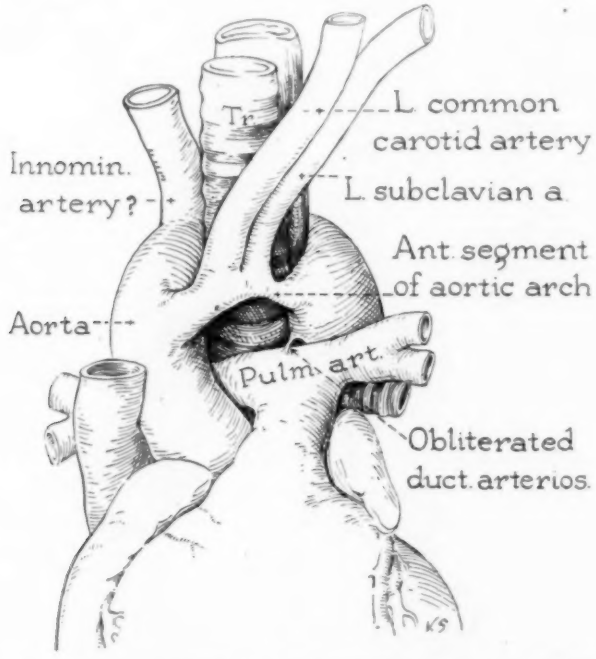

Fig. 4 (case 2).—Double aortic arch as seen at operation.

ward and the mediastinum opened. A double aortic arch with an arrangement of vessels as shown in figure 4 was seen. The anomalous segment of vessel extended from the left subclavian artery to the descending aorta. This anomalous vessel and an obliterated ductus arteriosus directly inferior to it pulled on the wall of the aorta and produced a pronounced bulge. Both the left common carotid and the left subclavian arteries arose from the anterior segment of the arch and crossed the trachea anteriorly. The vessel on the right, labeled the innominate artery with a question mark in figure 4, could not be well visualized. Whether it was a normal innominate artery or either of its branches could not be determined at operation. The anomalous anterior segment of the aortic arch was clamped, cut and sutured. The fibrous ductus arteriosus was cut (fig. 5). On release of these two structures, the aorta moved laterally and pressure on the trachea was relieved. The bulging portion of the aorta was attached to the pleura of the thoracic wall

with a silk stitch, to prevent its reattachment to the subclavian artery. The left subclavian artery was rather free after its attachments to the aorta were severed.

The lung was reexpanded, a drain inserted through the sixth interspace and the chest closed in layers with fine running sutures of surgical gut. The skin was closed with silk suture.

The postoperative course was stormy for a few days, because of tracheal irritation. Uneventful recovery followed, and on Nov. 18, 1947, the boy was dismissed from the hospital tremendously improved. Since then he has continued to improve. He still has a somewhat "brassy" cough, but in general he is relieved of his distressing symptoms.

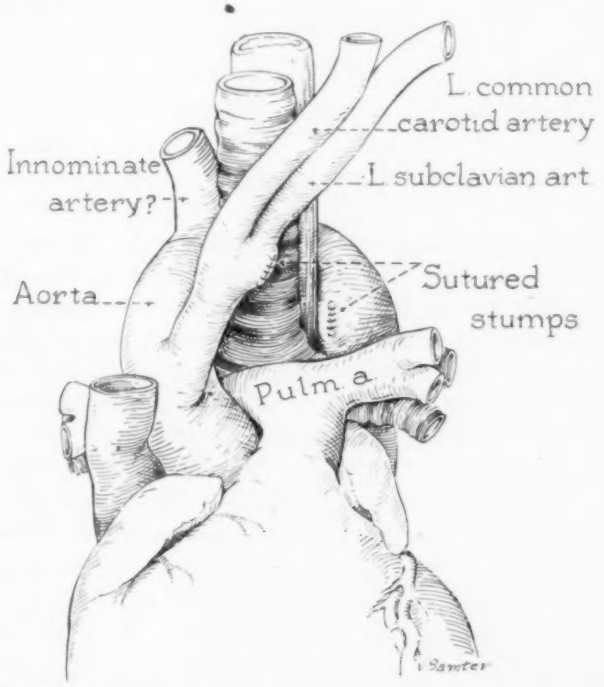

Fig. 5 (case 2).—Operative procedure—anterior segment of aortic arch and obliterated ductus arteriosus cut.

SUMMARY

Laryngeal stridor, noisy labored respiration, dysphagia, frequent infections of the upper part of the respiratory tract and choking spells often associated with cyanosis recurring in an infant should make one suspicious of a constricting double aortic arch.

The diagnosis can be established fluoroscopically and roentgenologically. With the infant in a lateral position on the fluoroscopic table a barium sulfate swallow will help demonstrate a concave shadow in the posterior wall of the esophagus.

Two cases of double aortic arch are reported.

707 Fullerton Avenue.

TANTALUM GAUZE IN THE REPAIR OF LARGE POSTOPERATIVE VENTRAL HERNIAS

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D. EMERICK SZILAGYI, M.D.

AND

MAGDA PUPPENDAHL, M.D.

DETROIT

THE RESULTS of the conventional methods of repair of large postoperative ventral hernias have been disappointing. These hernias are usually the result of concealed or manifest wound disruption and are characterized by loss of tissue substance, in particular by loss of fascial tissue, of the abdominal wall. This tissue deficiency together with the developmental scantiness of the musculofascial structures of the obese abdominal wall in which these hernias so often occur creates a problem of repair which is seldom solved successfully with the common surgical methods. The problem in reality is to replace and reconstruct the missing portion of the abdominal wall. Many of the popular procedures of repair merely aim at closing the hiatus by whatever means will allow it to approximate its edges. Thus, often these repairs amount to no more than the suturing together under great tension of scarred and attenuated fascial margins. Where attempts are made to avoid sewing under tension by turning fascial flaps and making relaxing incisions, the weakness is only spread further afield in an abdominal wall which has already proved itself defective. In either case, recurrences will be common.

Obviously the physiologically sound principle of repair in these hernias is to place a patch into the gap in the tissues. The material to serve as a patch around which the abdominal wall can be reconstructed may be tissue borrowed from the patient's body, such as fascia lata [1] or cutis grafts, or it may be some appropriate foreign substance. Fascia lata grafts, either free or pedicled, have a useful place in the

From the Division of General Surgery, Henry Ford Hospital, Detroit.

Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 20, 1948.

1. Foshee, J. C.: Fascia Lata Regeneration, Surgery **14**:554-549 (Oct.) 1943. Morse, L. J., and Barb, J. S.: Free Autoplastic Transplants of Fascia Lata in the Repair of Large Incisional Hernias, ibid. **13**:524-534 (April) 1943. Wangensteen, O. H.: Repair of Large Abdominal Defects by Pedicled Fascial Flaps, Surg., Gynec. & Obst. **82**:144-150 (Feb.) 1946.

repair of these hernias, but they also have serious shortcomings, among which the most important one is the lack of sufficient tensile strength for defects of large size, of over 8 cm. in diameter. Besides other disadvantages, cutis grafts present the same objectionable quality.

Thus, the need has been real and well recognized for a substance from which implants could be shaped for use in bridging large tissue defects of the abdominal wall. The ideal material would be chemically inert, biologically nonirritant, pliable, workable and strong. The search for such a substance has been long and disappointing. Among the many substances that have been more recently tried out as implants in divers situations in the human body, stainless steel, vitallium and tantalum appear to have manifested the most commendable features.[2] Tantalum in particular seems to possess qualities that would readily suggest its use for the purpose just mentioned.[3]

Tantalum, in contrast to stainless steel and vitallium, is not an alloy but an element (with the symbol of Ta, an atomic number of 73 and an atomic weight of 180.88). Chemically it approaches glass in resistance to acids and alkalis. These characteristics make this element likely to be inert in the physicochemical environment of animal tissue. Much clinical and experimental evidence seems to bear out this supposition. In addition, tantalum possesses high tensile strength, ductility and malleability, qualities that make its handling relatively easy. The strength of unannealed tantalum is similar to that of cold rolled steel. It can be drawn into a fine wire and the wire woven into cloth, gauze or screen. It becomes work-hardened (fatigued) at a much slower rate than most other metals used surgically. It is reasonably inexpensive.

ANIMAL EXPERIMENTS

In order to test the suitability of tantalum in the bridging of tissue defects of the abdominal wall, in October 1944 experiments were begun in dogs by one of us (M. P.). Tantalum gauze rather than sheet was used on the supposition that the porous structure of a mesh would better serve as a scaffold for the growth of connective tissue. Weaves

2. (*a*) Burke, G. L.: The Corrosion of Metals in Tissues, and an Introduction to Tantalum, Canad. M. A. J. **43**:125-128 (Aug.) 1940. (*b*) Venable, C. S., and Stuck, W G.: A General Consideration of Metals for Buried Appliances in Surgery, Internat. Abstr. Surg. **76**:297-304, 1943; in Surg., Gynec. & Obst., April 1943.

3. Burke.[2a] Carney, H. M.: Experimental Study with Tantalum, Proc. Soc. Exper. Biol. & Med. **51**:147-148 (Oct.) 1942. Gardner, W. J.: Closure of Defects of the Skull with Tantalum, Surg., Gynec. & Obst. **80**:303-312 (March) 1945. Olson, C. T.: The Place of Tantalum in Surgery, Indust. Med. **13**:917-920 (Nov.) 1944. Throckmorton, T. D.: Tantalum Gauze in the Repair of Hernias Complicated by Tissue Deficiency: A Preliminary Report, Surgery **23**:32-46 (Jan.) 1948.

of 50 by 50 and 100 by 100 mesh made of 2, 3 and 5 mil (1 mil equals 0.001 inch) wire were tried. Technically the 50 by 50 mesh of 3 mil wire handled most easily, and it best combined a maximum of strength with a minimum of bulk.

Defects were made in the abdominal wall of 10 dogs by excising uniform portions of all the layers save the skin and peritoneum. In 6 dogs a 2.5 cm. segment of the entire width of the left rectus muscle was excised above the level of the umbilicus. In dogs 1, 2, 3 and 4 the defect was filled in with a piece of tantalum gauze 3 by 3 cm. in size, which was sutured to the adjacent musculofascial structures by means of 4-0 tantalum wire. In dogs 1 and 2, 0.5 cm. of sulfanilamide powder was sprinkled into the wound. In dogs 5 and 6, the defect was not repaired beyond closing the skin over it.

In dogs 7, 8, 9 and 10 the musculofascial defects were made bilaterally in the combined oblique and transversus muscles on each side of the rectus muscle in the upper part of the abdomen. In dogs 7 and 8, the defect on the left side was repaired with tantalum gauze that was sutured in place as in dogs 1, 2, 3 and 4, while in the defect on the right side the tantalum screen was left unanchored. Finally, in dogs 9 and 10 the left-sided defect was repaired as in dogs 7 and 8, while on the right side no tantalum gauze was placed in the defect.

Dogs 1 and 2 (the ones in which sulfanilamide powder had been used) were reoperated on in three and four weeks, respectively. The wounds of both were grossly infected, and these animals had to be discarded from further considerations. At the time of reoperation a small degree of connective tissue growth could be noted about the pieces of tantalum gauze.

Of the remaining animals, in dogs 5 and 6 (controls, without repair of the defect) there developed large hernias. Rather surprisingly, the hernia in dog 6 healed spontaneously in three months.

Dogs 3, 4, 7, 8, 9 and 10 were investigated by reopening the operative sites at intervals of three to four weeks and six to eight months. A progressive envelopment by firm fibrous tissue of the tantalum implants could be observed. The connective tissue grew into the crevices of the tantalum mesh and gripped the wire trellis firmly. In four weeks the formation of the fibrous sheath was well under way, and in six months it was complete. The repair of the artificial defects was equally effective in the rectus muscle and in the oblique and transverse muscles. Anchoring the tantalum gauze appeared to aid the formation of new connective tissue, possibly by preventing excessive mobility of the implant. In 2 dogs small infected sinuses that developed after superficial wound infection did not interfere with the effective healing of the repair.

CLINICAL EXPERIENCES

The results of animal experiments were encouraging enough to justify a trial with tantalum gauze in clinical cases. Between Jan. 22, 1945 and Jan. 22, 1948, in 24 cases of postoperative ventral hernia repair was done with the aid of tantalum gauze implants. Not all the incisional hernias seen during this time were dealt with in this manner. Where the tissue defects were small (4 to 5 cm. or less across) and the abdominal wall strong the conventional methods of surgical repair were used and found adequate.

CLINICAL MATERIAL

Of the 24 patients in this group, 14 were women and 10 men. Their average age was 52.2 years, with a range from 35 to 77 years. All were obese, being from 10 to 40 per cent overweight. The original operation that preceded the appearance of the hernia was appendectomy in 9 cases, cholecystectomy in 4 cases, hysterectomy, "laparotomy" and uterine suspension in 2 cases each, and gastrectomy and inguinal hernial repair in 1 each; in 1 case the hernia followed childbirth; in another case the cause was not an operation but rather the presence of diastasis recti, and in 1 case the nature of the original operation was unknown.

A low midline incision was the site of the hernia in 8 cases, a low and a high right rectus incision in 5 each and a McBurney, Davis and a right lower abdominal quadrant stab wound in 1 each. Five patients gave a clearcut history of wound disruption and 2 a history of wound infection following their original operation. The time that elapsed from the date of the original operative intervention until the time the patient became aware of the hernia varied widely. Eight patients had noticed the presence of a hernia before they had left the hospital, 8 within six months, 1 within from six to twelve months, 2 within from one to five years, 2 within five to ten years and 1 within from ten to fifteen years; 1 patient could not give this information.

Six patients had their hernias repaired once before. Two patients had three earlier repairs, and 1 had four. Six noticed a recurrence directly after the last repair, 1 six months later, 1 seven months later, 1 two years later and 1 five years later.

Six patients had symptoms of incarceration on or before admission. One required resection of the bowel at the time of repair.

Three of the patients showed the signs of pronounced hypertensive cardiac disease. Two had severe chronic bronchitis. Two had adenomatous goiter, 1 with hyperthyroidism. One each had chronic cholecystitis, rheumatoid arthritis and diabetes. One was subsequently discovered to have carcinoma of the small bowel.

During the physical examination of each patient an effort was made to estimate and record the size of the hernial sac and of the tissue defect

in the abdominal wall. By comparing these estimates with the measurements recorded in the operative notes one finds that the clinical judgment of these dimensions is rather inaccurate. In particular the size of the tissue hiatus is impossible to determine precisely before operation. The operative measurements of the tissue defects varied from 48 cm.² (8 by 6 cm.) to 480 cm.² (24 by 20 cm.), the average having been 167 cm.²

OPERATIVE MANAGEMENT

The obese middle-aged patient that is typically afflicted with large postoperative hernia is a poor operative risk. The preoperative preparation of these patients must be very painstaking. They should preferably lose some weight and come as close to their normal weight/height ratio as possible. The associated diseases, which are rather common, must receive careful attention. Patients that are likely to have pulmonary complications are best operated on in the warm season. The passing of a Miller-Abbott tube is useful in all cases and essential in those in which there are hernial sacs containing much small bowel.

The technic of the implantation of the tantalum gauze in the abdominal wall is simple. Certain principles of procedure, however, which we came to recognize as we continued to work with tantalum gauze implants should be stressed. These concern mainly the question of embedding the tantalum implant and its covering with fascial graft.

Closest at hand among the ways of placing the tantalum gauze into the abdominal wound would seem to be its simple anchorage into the anterior fascial layer as a reenforcing sheet over the completed repair. The repair itself, in this case, is performed in one of the conventional ways. A moment's reflection will show that this sort of application of the tantalum gauze adds little security to the original procedure. The integrity of the repair in this instance depends in reality on the suture lines deep to the tantalum implant. Should the former hold until the tantalum gauze is incorporated into the new growth of connective tissue the repair will be greatly reenforced by the latter, but until such a time the presence of the tantalum gauze is of no advantage.

To obtain the greatest degree of utility from the implant, the operation must be so planned that at the completion of the technical steps the tantalum gauze has at least partly replaced the missing portion of the musculofascial layer of the abdominal wall and has become a structural part of the latter. In searching for the best technical way of accomplishing this, one is helped by remembering the behavior of the tantalum gauze in the animal experiments. In these experiments the implanted tantalum gauze was observed to be ensheathed in the proliferating connecting tissue as the wound in the surrounding region healed.

This role of trellis or scaffold that the tnatalum gauze assumes has been well demonstrated in four observations we had the opportunity to

make in human beings. The first of these was in an early case of hernia repair in which infection occurred and in which it was thought advisable to remove the screen.[4] At the time of the second operation the tantalum gauze was so densely bound to the underlying tissue by means of innumerable pegs of connective tissue that had grown into its meshes that it could be freed only with great force. In 2 other patients that required laparotomies for reasons unconnected with their earlier hernia repairs, the new incisions were carried through the region of the abdominal wall containing the tantalum screen. The relationships of the screen to the structures of the abdominal wall could be closely examined, and the same conditions as mentioned previously were observed. In the fourth case the appearance of an area of necrosis in the upper skin flap of an extensive hernia repair permitted the direct observation of the region of the tantalum implant. The observations here were the same as previously noted.

Therefore, in order to facilitate the incorporation of the tantalum gauze into the abdominal wall, it would seem desirable to prepare a bed for it within the tissues. After some trials the most suitable location was found to be the plane between the peritoneal and musculofascial layers of the abdominal wall.

In nearly all large incisional hernias the tissue deficiency involves not only the deeper layers but also the external oblique fascia (or anterior rectus sheath, as the case may be). After placing the tantalum gauze in its bed, therefore, often a portion of it remains uncovered for lack of sufficient anterior fascial layer. It was a matter of much speculation whether it was desirable to cover this bare area with a fascial graft or to allow it to remain without fascial covering, that is, directly adjacent to the skin. The conclusion was accepted that the area should be covered with a fascial graft for the following reasons: First, in a normally healing wound a fascia lata graft is soon integrated with the recipient tissues; once it has established its blood supply, a fascia lata graft will most likely act as a second outer proliferating layer to enclose the tantalum screen in a sheath of connective tissue. Secondly, if the subcutaneous fat pad is thin the tantalum gauze tends to stick to the skin and gives an unpleasant cardboard effect. An intervening fascial layer prevents this. While most of these patients have abundant subcutaneous fat, the hernia sac is often so superficial that its dissection leaves skin flaps with little adiposity. Finally, it was thought that a fascial covering may protect the tantalum, at least during the first few postoperative days, in case of wound infection. Curiously enough,

4. In a similar case at the present time we would hesitate to do so. Tantalum wire sutures when placed in infected wounds do not behave like silk or many another nonabsorbable material; they do not form a nidus of suppuration, and they do not sequestrate. Tantalum gauze appears to act in a similar manner.

the first and the last of these assumptions were thoroughly confirmed by observations in a recent case (already mentioned) in which a large area of necrosis developed in the upper skin flap, thus exposing the lower third of the tantalum gauze and its fascial covering. During three weeks of healing, the gradual incorporation of the fascial graft into the tissues of the abdominal wall could be observed and photographed. Only a small area overlying the center of the exposed tantalum screen died and had to be trimmed away. By this time (fourteen days postoperatively) the granulation tissue had grown through the meshes of the screen, giving it a new covering suitable for skin grafting. Against these advantages, the only valid objection to the use of a fascial graft is that its preparation requires additional operative time. With proper team work, however, this time can be reduced to insignificance. In the cases in which we operated we covered the gauze with fascial graft thirteen times.

Based on these considerations, the steps of the technic of implanting the tantalum gauze are as follows:

A graft is taken from the fascia lata of the thigh opposite the side on which the operating surgeon stands (the latter being almost invariably the right side). In deciding the size of the graft one can have little reliance on the palpable dimensions of the defect in the abdominal wall. There would seem to be no anatomic contraindication to the removal of very extensive sheets of fascia lata, but it has been observed that it is a wise compromise to utilize only the lateral aspect of its extent from about the lower attachment of the tensor muscle to a point 8 to 10 cm. above the tibial attachment. This dissection can be carried out in ten minutes and yields a graft from 20 to 30 cm. long and from 10 to 15 cm. wide. (The skin incision of the thigh is closed by an assistant to save time.)

A transverse incision is now made across the summit of the hernial sac and centered as closely as possible on the hiatus in the abdominal wall. The skin and subcutaneous tissues are separated by sharp dissection from the hernial sac along the full expanse of the latter until the anterior fascial layer is reached along the whole circumference of the sac. The dissection is now carried fan-wise outward from the neck of the sac for a distance of about 10 to 14 cm. This additional dissection greatly eases orientation in judging the portions of the musculofascial layers that can be put to use in the repair.

The neck of the sac is now carefully defined all around the tissue defect, and then the sac is opened. The contents of the sac are freed and replaced in the peritoneal cavity. By palpating from within the peritoneal cavity one can clearly determine the status of the operative scar adjoining the tissue defect. Often additional areas of attenuated and scarred fascia are discovered along the line of the old incision. The

hiatus proper is enlarged by cutting across these areas of weakness until the limits of a firm healthy musculofascial layer are encountered.

In the further dissection of the abdominal wall one's effort is directed to define two layers: the peritoneal layer and the musculofascial layer. While these two layers are practically always capable of being identified, further anatomic definition of the components of the abdominal parietes is usually undesirable and even impossible, because of the scarring and distortion of the structures that have been disturbed before, often repeatedly. The so-called peritoneal layer comprises not only the peritoneum but also the transversalis fascia and often also the posterior rectus sheath; it is, of course, continuous with the wall of the hernial sac. The musculofascial layer is equivalent to the combined layers of the external and internal oblique and transverse muscles when the dissection is outside the rectus sheath and to the rectus muscle and its anterior sheath when the dissection is through the latter.

After the attenuated operative scar and the actual tissue defect has been turned into one hiatus, the peritoneal layer is separated with sharp and blunt dissection from the musculofascial layer along the entire length of the gap. The dissection is carried beyond the margins of the hiatus in order to extend for a distance of 3 to 4 cm. under normal musculofascial structures all around. It is this added dissection that opens the bed into which the tantalum gauze will be laid.

Now the hernial sac is so trimmed that a sufficient portion of its wall is left to be closed without tension with a running stitch of heavy silk. A piece of tantalum gauze is next cut to a size and shape to fit into the bed prepared for it. The musculofascial layer is now shorn, all the scarred and worn-out portions being cut away. Thus, a margin of 3 to 4 cm. of firm musculofascial structures is left to fall on and to overlap the edges of the tantalum gauze. This firm tissue margin is then sutured with mattress stitches of 3-0 tantalum wire to the edges of the screen. (These stitches pass from outward in, through the musculofascial substance and tantalum screen, then under the screen and out through it and the musculofascial layer.) One should carefully avoid putting tension on the sutures by attempting to pull the edges of the defect together. Even so, usually some reduction of the size of the original defect will have been obtained when the anchoring of the tantalum gauze is completed.

There remains now a varying expanse of the tantalum screen uncovered by fascia. The fascia lata graft is placed over this and is sutured to the overlapping margin of the musculofascial layer. The suture material is again 3-0 tantalum wire.

The extensive subcutaneous area of dissection is drained with a soft rubber drain. The skin is closed with vertical mattress stitches of

6-0 tantalum wire. A snug dressing is applied and held in place by elastoplast.

Those patients that present a fat apron in company with the incisional hernia (and this is a common occurrence, 6 of our patients having had this combination) must receive special technical considerations. If the hernia is in the lower part of the abdominal wall, the skin incision is so placed that it encloses the fat apron. If the hernia is in the upper abdominal regions, a separate incision is used to deal with the fatty fold. Excision of a fat apron always increases the danger of wound infection, and it often impedes healing. In many cases, however, it cannot be avoided, either because of the need for approach or because of reasons of postoperative wound dressing. We have observed that if the dissection of the fatty apron is done with fast strokes of an amputation knife and without too much undercutting healing is faster and cleaner.

Among the measures that the postoperative care of these patients demands, the importance of early, and whenever possible immediate, rising should be stressed.

RESULTS

As regards postoperative results, these patients can be considered from two points of view. First, one may inquire how the body tissues tolerate the presence of tantalum screen. Secondly, one may seek to determine the permanency of the repair. We have followed up our patients for periods ranging from one month to thirty-seven months, or for an average of thirteen months. After this time the first point of inquiry can be answered with some accuracy while the second one must receive a guarded reply.

In the immediate postoperative period wound complications were somewhat less common than one could expect in such extensive procedures. There was one wound infection in an early case in which a lipectomy was combined with the hernial repair; in this instance the tantalum screen was removed on the twenty-seventh postoperative day and the skin was closed secondarily. The hernia did not recur for eight months, when the patient was lost sight of. In another wound a skin flap underwent extensive necrosis, but at the time of writing the wound was healing and the abdominal wall had remained intact. The only persistent complication was the accumulation of a clear serous fluid in the area of subcutaneous dissection in 11 cases. This, too, was more annoying than grave. With repeated aspirations the wounds became dry in from ten days to thirteen weeks, or on the average in thirty-three days. The fluid collection did not interfere with wound healing. On the average, the patients were discharged on the fifteenth postoperative day. There was no operative death.

During the stated periods of observation none of the patients had symptoms that could have been referred to the presence of the tantalum gauze. In patients with thin skin and the tantalum only partially covered by fascia, the screen may be the source of an uneasy feeling of stiffness, which, however, is of little import.

There was only one recurrence, and this was in the third case of the series. About two and a half years after the repair a progressive protrusion was noted in the lower half of the operative scar. On examination this bulging appeared to be due to a diffuse stretching of the scar rather than to a true hernial defect. The patient was comfortable, but was advised to have a new repair. This was an instance in which the tantalum screen was not embedded but merely anchored to the anterior fascial layer, in the manner of reenforcement of the repair of a conventional pull together type.

In the follow-up period the fate of the tantalum gauze was observed in progress roentgenograms. Some fragmentation of the gauze was often noted, without any evidence, however, that the breaking of the screen in any way weakened the repair. The reconstructed abdominal walls remained firm, nontender and of normal outline.

The fragmentation of the tantalum screen was to be expected, of course, since all metals become work-fatigued. The fact that the loss of the continuity of the metal screen did not result in recurrences is a further proof of the role of the tantalum gauze as a framework. Apparently this role is most important during the first four to six postoperative weeks, at the end of which time the newly formed connective tissue sheath surrounding the screen is capable of maintaining—at least for the duration of these observations—the integrity of the repair even if the holding power of the implant is gradually lost.

These results, therefore, must be regarded as satisfactory enough to warrant further application of the method.

SUMMARY

The fundamental pathologic characteristic in cases of large postoperative ventral hernias is a defect in the tissue of the abdominal wall. No repair of these hernias is entirely satisfactory unless it provides for the bridging of the tissue defect with an autoplastic or exogenous graft. Because of the limitations of autogenous grafts, a need exists for some extraneous material to be used for this purpose. The suitability of tantalum (a biologically highly inert metallic element) in the form of a gauzelike weave has been tested experimentally in 10 dogs with favorable results. The same material was employed in the repair of twenty-four large postoperative ventral hernias. The composition and clinical characteristics of this series are presented.

An operative technic is described that aims to incorporate the tantalum gauze as a structural part of the abdominal wall. The operative results are described. There was no operative death. In a period of observation of from one to thirty-seven months, one recurrence was noted. The presence of the tantalum implants caused no untoward symptoms.

The part of the tantalum gauze in the repair is explained as that of a scaffold, which, providing temporary support for the reconstruction of the abdominal wall, also affords a framework or trellis for the growth of new connective tissue which eventually takes over the role of maintaining the integrity of the abdominal wall.

CONCLUSION

After a rather short period of observation, tantalum gauze has been found useful as an extraneous graft for bridging tissue defects in large postoperative ventral hernias. Continued trial of the material seems justified.

The tantalum gauze used in this study was obtained from the Ethicon Suture Laboratories, New Brunswick, N. J., through Dr. Herbert L. Davis.

END RESULTS OF EXCISION OF THE CARPAL BONES

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DESTOT, in his monograph "Injuries of the Wrist," translated from the French and published in 1925,[1] referred to the carpal navicular and the lunate bone as the scapholunary system. He stated that this system forms the intermediary joint between the radius and the capitate, and it is responsible in a large measure for the amplitude of movement that the wrist enjoys. This position, which makes these bones important, also makes them vulnerable, for it places them in a wedge, as it were, caught between the anvil of the forearm and the hammer of the distal row. These two bones also participate in the formation of the carpal arches, both the transverse and longitudinal; in fact, the lunate is the keystone of the arch. It is situated at the apex of the excavation of the palmar groove which gives passage into the palm of certain of the nerves, tendons and blood vessels of the hand and fingers. This groove is bounded by two pillars, the navicular and greater multiangular bone on the radial side and the pisiform and the unciform process of the hamate bone on the ulnar side. These pillars are an important part of the thenar and hypothenar eminence.

The head of the capitate bone (that is, its proximal end) is the common center of the movements of the wrist. It is a kind of rudder, merely tilting while the satellite bones around it describe a varied movement pattern. That this pattern is wider and more varied than most persons think has been illustrated by Destot, Speed and, more recently, by cinefluoroscopic methods.

The scapholunary system is a "supple and movable meniscus"—supple in its ability to conform with any position of the hand and capable of purposeful movement in its relationship to the radius and the mid-carpal joint. Proof of these points in regard to the position and function of this system is, of course, found in the frequency of the lesions seen in these bones. It is not the purpose of this paper to discuss the nature or treatment of specific lesions, but rather to point out some of the changes that may be expected over a period of years in the wrist

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1. Destot, E.: Injuries of the Wrist: A Radiological Study, London, Ernest Benn, Ltd., 1925.

as a functional unit, which changes are the result of certain methods of treatment or of neglect.

The wrist reacts to inflammation, whether traumatic or not, whether acute or chronic, in three general ways. First, an acute onset is followed by capsular and ligamentous fibrosis. All the joints that make up the radial carpus and carpus intercommunicate, so that simple effusion, hemorrhage, suppuration and the like and the residual fibrosis will not be confined to any single space but will be widespread.

Second, the wrist reacts by cystic change in the carpal bones, the distal end of the radius and proximal ends of the metacarpal bones. These cystic areas are caused essentially by the chronic hyperemic state induced by the primary lesion. Why it is selective is not known, but the bones

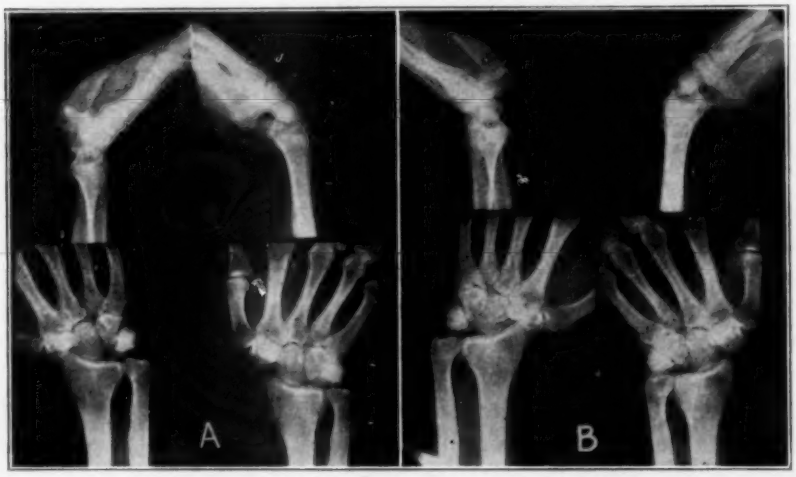

Fig. 1.—*A*, the right wrist of a locomotive fireman thirteen years after excision of the navicular and lunate bones for a fracture of the former, with displacement of fragments and dislocation of the latter. The wrist had enough mobility and power to carry on the general duties of this occupation. The upper left figure is the dorsiflexion position and the upper right the volar flexion. The lower left shows the wrist in radial deviation and the lower right in ulnar deviation. No appreciable arthritic change in either the radiocarpal or the intercarpal joints can be seen. Also, there is an absence of cystic changes so frequently noted in long-standing lesions or malalinement of the carpus. *B*, left wrist of the same patient. The motions are essentially the same as those in *A*, and it may also be noted that there is again an absence of undesirable cystic or cartilaginous changes.

bearing the burden of movement and the direct application of forces are more frequently involved. In a way it may be said that these involved parts never recover from the initial osteoporosis. The osteolytic action continues and localized replacement by fibrous tissue takes place. The cavity usually contains, besides fibrous tissue, amorphous calcific material and a little fluid. The relatively dense confining layer seen in the roentgenogram will contain some necrotic bone, and the

hyaline cartilage underlying this cystic defect will be in a varying state of necrosis with or without attempt at fibrocartilage replacement. The presence of these cysts, induced originally by the initial hyperemia, serve also to continue it, because of the necessity to dissolve and carry away the contents of the cavity and to effect replacement by new bone if possible. Rodholm and Phemister have drawn an analogy between

Fig. 2.—*A*, right wrist of a man (E. W., 47 at the time of writing) engaged in the general practice of dentistry, from whose wrist the navicular and lunate bones were excised in 1936, because of an ununited fracture of the navicular bone with cystic change in the line of fracture and arthritic change in the radiocarpal joint. The slight enlargement of the lower end of the radius has persisted, but certainly no noticeable arthritic change is present. There is a small amount of retained bony debris in the space between the lesser multiangular bone and radial side of the capitate bone. No cystic change is evident in any of these bones. *B*, the same patient. This shows the range of dorsiflexion on the wrist and the amount of volar flexion possible on the right.

these lesions and those that occur in the head and neck of the femur and the acetabulum in degenerative diseases of the hip joint.

Third, the wrist reacts by arthritic change. This change may be brought about by the cystic lesion previously described, resulting in the necrosis of underlying cartilage, or the cartilage may be directly destroyed by the friction of a necrotic bone or a fragment acting as a foreign body in the working mechanism of the joint—the so-called sand in the bearing picture which is essentially traumatic arthritis. Whatever the basic cause, the end result is the approximation of bony surfaces and the mixed fibrosis and bony ankylosis that follow.

The fibrosis, cystic change and arthritis may also be brought about by a slowly developing, or chronic, process over a period of years by the gradual realinement of the carpal bones necessitated by the loss of one of the two members of the scapholunary system. For example, if a substantial fragment of the scaphoid (navicular) or the entire bone is removed ill advisedly for, let me say, an early nonunion, before necrosis has taken place and before any traumatic arthritic change has developed in any of the contiguous joint surfaces, a certain readjustment will result. This will consist principally in the attempt of the capitate bone to approximate the articular surface of the radius. This is caused by the action of the tendons of the wrist and hand and the gradual shortening and tightening of the ligaments. As this goes on the lunate bone will be gradually displaced toward the ulnar side of the wrist. The "supple and movable meniscus" mentioned before will be disrupted, and the lunate alone will be unable to describe its varied pattern of movement around the rudder of the capitate bone's proximal end. The lunate bone, in effect, is trapped and becomes literally a supernumerary of the proximal row. Its attempt to conform to the demands made on it result in a stretching, or overstrain, of the ligaments, and this initiates a chronic inflammatory process. This in time will be followed by the fibrosis, the cystic change and the cartilaginous degeneration described before. The last-named condition will be enhanced by the scraping effect of any cartilaginous surface that is working out of alinement, and, in this sense, it is analogous to the chondromalacia of the patella that develops when this bone rides laterally over the femoral condyle in instances of extreme valgus deformity of the knee. It is also seen in the ankle if the medial lateral alinement of the leg is altered, although in this instance the factor of weight bearing enters the picture; but then the direct and torsional forces applied to the wrist of a laboring man can certainly be as great as those applied to joints of the lower extremity in usual weight-bearing activity.

Having these changes in mind, and being presented with a patient who complains of pain, weakness and limitation of motion of long standing in the wrist, one cannot reasonably expect to alter this situ-

ation by the excision of a single fragment or of a single bone of the proximal row. Whether the lesion be in the entire navicular bone, confined to the proximal pole alone or the lunate alone, the generalized changes in the capsules, ligaments and cartilage will not be reversed. On the contrary, it is possible to make them even worse by hastening the disalinement of the navicular and/or lunate on the capitate bone. The changes in relationship that occur after removal of the lunate are not as striking as those that follow removal of the navicular bone. The latter changes are so extensive and so progressive over a period of time that one wonders whether this bone alone should ever be excised. The excision of both these bones, however, that is, of the entire scapholunary system, seems to be a more logical treatment when one considers the long range changes that occur. The supporting ligaments on the radial

Fig. 3.—*A*, a dentist (O. P., aged 53) who, in 1936, had excised the navicular bone alone, because of pain due to arthritic change following an ununited fracture with necrosis of the proximal fragment. On the left side it will be noted that the capitate has forced the lunate bone toward the ulnar side of the wrist, making it impossible for the latter bone to participate in normal articulation. In the lateral view of the left side it can also be seen that the lunate bone is being forced toward the volar surface of the wrist and that its notch does not enter the articular surface of the capitate bone. The density of the lunate suggests that it is undergoing necrosis. In the right side on the illustration it will be seen that the greater multiangular bone was removed along with the navicular. The same change in the relationship between the capitate, the lunate and the radius has occurred on the right as on the left, and the shortening of the thumb is evident because of loss of support of the greater multiangular bone. *B*, the extreme restriction of motion of both wrists in the radiocarpal joints is shown. The arthritic change, spur formation and development of debris is seen.

and ulnar sides of the wrist will be responsible for the maintenance of good stability and will guide the capitate into a satisfactory articulation with the distal radial surface. Because of these supporting structures, no significant deviation, either functional or cosmetic, need be expected.

The excision of these bones constitutes a type of arthroplasty and an unusually favorable one, in that no autogenous, heterogenous or synthetic substances need be interposed, because there remains hyaline cartilage to line the surfaces soon to oppose each other in motion. It need not be emphasized that the success of the procedure will depend, at least in part, on maintaining the integrity of this cartilage or such of it as remains. Substantial roughening at the time of excision would, of course, set the stage for the development of arthritic changes which,

Fig. 4.—The wrist of a 55 year old man with a known nonunion of the carpal navicular bone, following fracture thirty-five years previously. Extensive arthritic change in the radiocarpal joint can be seen, with necrosis of the navicular bone, particularly in the proximal fragment, and extensive cystic change occupying practically the entire body of the lunate bone. The displacement of the lunate bone toward the ulnar side of the wrist is evident on the anteroposterior views, and its displacement into the volar aspect of the wrist is evident on the lateral views. This latter displacement produced mild irritative symptoms of the median nerve. This is the type of wrist in which a painless range of reasonable motion cannot be expected by any excision of the carpal bone, and a fusion of the joint, preserving the rotatory motion in the distal radioulnar joint, is the procedure of choice.

in turn, could lead to the fibrosis and cystic degeneration mentioned before.

Nine wrists in 7 patients have been followed for a period of ten to thirteen years. Excision of the navicular and lunate bones was done, for a combined fracture of the navicular, with substantial displacement of the fragments and an associated dislocation of the lunate bone, or for nonunion of a fracture of the navicular bone alone, with cystic or arthritic change advanced enough to contraindicate a bone graft. Of course, there are severe situations which would make a fusion of the wrist a preferable procedure, but these are not within the scope of this paper. The most favorable result, from the standpoint of strength, alinement and range of motion, can be expected in those instances in which the two bones are removed as the primary treatment, as after the combined fracture and dislocation. In the other types, in which minor arthritic changes have already developed, the limitation of motion already present due to the generalized fibrosis in the wrist will probably not be overcome, but a reasonable assurance can be given that pain will be relieved and that further change will not take place. Normal range of motion cannot be expected in any event, but a painless stable useful range may be expected.

DISCUSSION

Dr. Kellogg Speed, Chicago: Three factors are helpful in the type of excision advocated by Dr. Stack: (1) The arrangement of the ligamentous support of the wrist which is never ruthlessly cut away helps, (2) the normal cartilage-covered roundness of the proximal surface of the capitate is favorable, and (3) the arching protective surface of the distal end of the radius which is likewise covered by cartilage helps in this movement, as Dr. Stack has described. One often does not realize that there are fractures in more than one bone. Once sufficient room is gained by the removal of the offending bones of the proximal row, along with their often undiscovered pathologic structures, a setup equal to a major arthroplasty is formed, and, as there is no bared bone exposed, there is no tendency to form periarticular bone which might ultimately threaten the mobility of the newly acquired articulation. The ligamentous construction is such that one may excise without really damaging the enveloping tissues, particularly the strong collateral ligaments, and leave a good control over the displacement. The navicular bone is a struggler between the two rows, and, once it is removed, the capitate bone takes up the function and rotates against the articular surface of the radius. When the proximal row of bones is removed, the capitate bone is free to articulate with the radius. Surgeons have tried to take out one bone, and the operation failed. I believe that complete removal of the navicular bone is a difficult and tedious job, because one does not wish to injure the cartilage of any neighbor. It can be taken out rather cleanly, leaving no bone or cartilage behind. After doing this, one thrusts pressure against the lunate bone and may cause the development of new bone or cartilage on the articular surface of the radius. When one studies these bones after removal, looking at the lunate bone carefully, one will observe that it likewise may have undergone a fracture or splitting that one does not recognize in the roentgenogram. Once the proximal row has been removed, the capitate bone will slowly come back with the help of those ligaments which I have pointed out, and there is then an articulation between the proximal surface of the capitate bone and under surface of the radius which allows all that range of motion.

In these mixed-up lesions, such as the transnavicular-perilunar dorsal dislocation of the wrist in which the bone cannot be replaced or is dead or fractured, one should take the bone out, which leaves a space which gradually closes up and gives a proper articulating surface without the formation of new bone, for the reasons that I stated. One example of the same type of lesion—the transnavicular-perilunar dorsal dislocation—presents a picture with a hump not unlike the Silver fork deformity after Colles' fracture. But after removal of that proximal row it is difficult to tell which wrist was damaged and which bones were removed. In case of fresh injury with dislocation of the bones, I believe that, although some men have put these back successfully, most of us would be glad to remove them completely. Dr. Callahan of Chicago has put some back, and they have functioned rather well.

RESECTION OF THE TRACHEA

An Experimental Study and a Report of a Case

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TRACHEAL obstruction by a primary tumor is customarily treated by endoscopic methods, namely, piecemeal removal of tissue projecting from the wall of the trachea, diathermic cautery of the base of the tumor and dilation. Such procedures have sufficed to relieve many patients of their symptoms for months. Because a fairly large proportion of primary tumors in the trachea are cylindromas, which invade little beyond the trachea and grow slowly, control of the tumor may be possible for several years. Obviously, however, a more nearly ideal treatment would conform to the accepted principle of surgery in neoplastic disease: complete excision of the tumor, the tumor-bearing region and a surrounding margin of normal tissue. The rareness of tumors of the trachea has, on the one hand, provided little incentive to develop a method of radical surgical treatment, and, on the other hand, the hazards which come to mind in the contemplation of a possible operation discourage its consideration.

Our purposes in this study were to determine whether a length of trachea, such as might be removed for a tumor of limited size, could be resected and a leak-proof anastomosis made and whether a tube of foreign material would cause undesirable effects when implanted in the trachea at the anastomosis for a long period. The study was designed with these purposes because we recognized that only a brief interval could be allowed between the time when the trachea was opened and the time when continuity was reestablished and because we reasoned that this requirement might be met by a method of anastomosis over a tube of foreign material, provided that the tube did not cause excessive local reaction or obstruct the outflow of tracheobronchial secretions.

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From the Division of Surgery, Mayo Clinic (Dr. Clagett), the Division of Experimental Medicine, Mayo Foundation (Dr. Grindlay) and the Division of Medicine, Mayo Clinic (Dr. Moersch)..

Tumors of the trachea are not common lesions. Tinney, Moersch and McDonald have reported data on 27 cases from the Mayo Clinic.[1] They observed that the tumors usually involved the lower third of the trachea. The posterior and lateral walls were the site of the lesion more frequently than the anterior wall. In 11 (41 per cent) of this series of cases the neoplasms were squamous cell carcinomas, in 8 they were cylindromas, in 6 they were adenocarcinomas and in 2 they were hemangioendotheliomas. The prognosis was much better for cylindromas than for other lesions. The 8 patients who had cylindroma had been followed up for various periods from six months to ten years. Only 1 of the patients who had cylindroma had died during the period of observation.

METHOD

A series of 22 healthy dogs was used in this study. Size, weight and age varied widely. All operations were performed with sterile technic and with the animals under general anesthesia. Intravenously administered pentobarbital sodium ("nembutal") was used for the first operations, because it was thought to be undesirable to use an inhalation anesthetic. Later we abandoned this anesthetic, because of its prolonged depressant effects, in favor of intratracheally administered ether. The dogs required no special postoperative care. Their clinical course was followed by bronchoscopic examinations, which were performed by one of us (H. J. M.) and Dr. H. W. Schmidt.

The tubes used for anastomosis in this study were made of polythene (polyethylene), one of the more recently developed plastics. Briefly, the method of manufacture of the tubes[2] consists in the fusing together by heat of several layers of thin polythene film, the film being tightly wrapped about a coated tubular mold. The wall thickness of the tubes varied between 0.015 and 0.020 inch (0.038 and 0.051 cm.). The proper length and diameter were determined by experience. We have found that the outside diameter should be the same as, or slightly greater than, the inside diameter of the trachea and that the length should be twice the diameter. At each end and in the middle of the tube is a narrow circular external ridge of polythene. A small thin tab, formed during the mold process, causes the middle ridge to have a projection at one point. The internal wall of the tube is perfectly regular and smooth.

The technic of resection of a segment of trachea and anastomosis of the remaining portions over a polythene tube is simple and requires little time. After the trachea has been freed from surrounding tissues, transverse incisions are made through the intercartilaginous membrane at the upper and lower ends of the segment chosen for removal. These incisions are carried only through the anterior

1. Tinney, W. S.; Moersch, H. J., and McDonald, J. R.: Tumors of the Trachea, Arch. Otolaryng. **41**:284-290 (April) 1945. Harrington, S. W.; Moersch, H. J.; Tinney, W. S.; McDonald, J. R., and Clagett, O. T.: Symposium on Certain Tumors of the Bronchi (Adenomas and Cylindromas) and on Tumors of the Trachea, Proc. Staff Meet., Mayo Clin. **21**:409-430 (Oct. 30) 1946.

2. Grindlay, J. H.: Method of Making Tubes of Polyethylene Film for Use in Anastomosis of the Common Bile Duct, Trachea and Pelvic Colon, Surgery **24**:22-29 (July) 1948.

half of the circumference. The trachea between the two incisions, the portion to be resected, is then split by a longitudinal incision, and a traction suture of braided silk is placed around the tracheal ring of both the oral and the caudal segments. Next, the surgeon places the polythene tube on the posterointernal surface of the split portion of trachea. While the assistant pulls the ends of trachea together with appropriate tension on the traction sutures, the surgeon manipulates the tube into the oral and caudal ends of the trachea. As soon as the tube is in position, the two traction sutures are tied together while they are held taut, and interrupted silk sutures are placed on each side of the united traction sutures.

At this juncture the partially resected segment is still attached posteriorly and is folded transversely. It is removed by the completion of the transverse incisions at each end, around the posterior segment of the circumference. One should cut for only a short distance at a time and place an interrupted suture before continuing the incisions. Firm anchorage of the tube is accomplished by passing one of the interrupted sutures through the substance of the central tab on the tube. When the anastomosis is complete, it will be found that the ends of trachea have been closely approximated and that little if any of the tube is exposed.

TABLE 1.—*Polythene Tube in the Trachea: Summary of Results in 22 Dogs*

Use of Polythene Tube	No. of Dogs Killed While Well	No. of Dogs That Died		No. of Dogs Living			Total
		With Tube in Place	With Tube Removed	With Tube in Place	With Tube Removed	With Tube Replaced	
Cervical anastomosis	3	3	2	2	1	2	13
Thoracic anastomosis	0	0	0	5	0	0	5
Thoracic implant	0	0	2	0	0	0	2
Bronchial implant	0	0	0	0	2	0	2
Total	3	3	4	7	3	2	22

RESULTS

Table 1 is a summary of all experiments. The first group of 13 dogs underwent resection of from three to eight cartilaginous segments (mean, 5) of the lower cervical portion of the trachea. Three of these dogs were killed for examination at various lengths of time after operation, 3 died between three and seven and a half months after operation, and 2 died when the tubes were removed surgically. Of the 5 living dogs, 2 have their original tubes in place, 1 has had the tube removed and 2 have had the original tubes replaced by new tubes.

The second group of 5 dogs underwent resection of four segments of the lower thoracic portion of the trachea; all are living and have their original tubes in place. The third group of 2 dogs had polythene tubes implanted through incisions in the lower part of the trachea; no resection was performed. Both dogs died after their tubes had been removed surgically. The last group of 2 dogs had tubes implanted without resection in the right or left main bronchus. These dogs are living, but both have lost their tubes.

Table 2 is a summary of 13 experiments in which resection of three to eight segments (mean, 5) of the cervical portion or four segments of the thoracic portion of the trachea was carried out and in which the tube was not later removed. The first 3 dogs of this group died suddenly of acute tracheal obstruction caused by the tubes becoming loose. Dogs 1 and 2 died at seven and a half months and seven months, respectively. They had been well, and an early bronchoscopic examination of each had shown no reaction about the tube. Necropsy revealed that the flanges at the ends and middle of the tubes had become loose and the main portion of the tube had obstructed the trachea by lodging obliquely behind the larynx. Dog 3 died suddenly three months after operation because the distal end of the tube had partly collapsed and a granuloma, which protruded and acted as a ball-valve obstruction, had

TABLE 2.—*Resection of Lower Cervical or Lower Thoracic Portion of the Trachea in Dogs and Anastomosis with Polythene Tube*

Dog	Segments Resected, Region	Bronchoscopic Examinations, Months Postoperatively	Period Observed, Mo.	Disposition or Present Condition
1	8, neck	1.5	7.5	Died, acute asphyxia from defective tube obstructing trachea
2	5, neck	1	7	
3	5, neck	1	3	
4	4, neck	1.5, 3, 7	10	Killed for examination of trachea and tube
5	3, neck	1	1.5	
6	5, neck	1.5	1.5	
7	4, neck	0.5, 2, 10, 12	13	Alive, well
8	5, neck	0.5	3	
9	4, thorax	1, 5, 9	12	Alive, well
10	4, thorax	1	3	
11	4, thorax	1	3	
12	4, thorax	0.5	2.5	
13	4, thorax	0.5	2.5	

grown between the tube and trachea at this point. Bronchoscopic examination at one month had shown a small accumulation of mucus distal to the tube. During the next two months there had developed slight stridor and cough, noticeable when the dog became excited.

The next three dogs of the group were killed in order that complete examination of tube, trachea, bronchi and lungs might be made. All three dogs had been well and free from cough or other symptoms. Bronchoscopic examinations of dog 4 at one and a half, three and seven months and necropsy at ten months showed no inflammation or retention of secretion. Dog 5, examined by bronchoscope at one month and killed at one and a half months, and dog 6, killed at one and a half months by an overdose of pentobarbital sodium during bronchoscopic examination, likewise, had no inflammation or accumulated secretion. Photographs of the opened trachea of dog 6 with the tube in situ are shown in figures 1 and 2.

Dog 7, with resection of four segments from the lower cervical portion of the trachea, and dog 8, with five segments resected, were living at the time when this paper was written, thirteen and three months, respectively, after resection. Dogs 9 through 13 have had four segments of the lower thoracic portion of the trachea resected and are

Fig. 1 (dog 6).—Trachea and lungs. The trachea has been opened longitudinally above and below the polythene anastomosis tube.

all living. Operation was done twelve months ago in the case of dog 9, three months ago for dogs 10 and 11 and two and a half months ago for dogs 12 and 13. All of these 7 dogs (dogs 7 through 13) have had good health, have maintained their weight and have been free from cough or abnormal breathing. The tone and pitch of their bark appear normal. Bronchoscopic examination was performed on these 7 dogs at two weeks or one month; in only 2 cases (dogs 7 and 11) was there

evidence of slight inflammation of the trachea adjacent to the tube. No sign of inflammation or retention of mucus was found in the other dogs at the time of early examination, nor were such signs found at later examinations in dog 7 (examined again at two, ten and twelve months) or dog 9 (examined again at five and nine months).

Table 3 is a summary of experiments on 9 dogs (dogs 14 through 22). Various procedures were performed on these dogs, but all have had their tubes removed surgically or have lost them spontaneously. Dogs 14 and 15 underwent resection of five segments of the lower cervical portion of the trachea. The tube was removed from dog 14 at two and a half months and from dog 15 at one and a half months. Both animals died at the end of operation. Dog 14 died from collapse

Fig. 2 (dog 6).—Close-up view of end of polythene tube in trachea.

of the trachea at the site of anastomosis, where the tracheal wall for a length of more than 1 cm. consisted only of fibrous tissue; at the time of anastomosis the tube had fitted very tightly and a gap of 2.5 cm. had been left between the ends of trachea. Dog 15 died because of a large tear that was made accidentally in the bifurcation of the trachea. Two weeks before death bronchoscopic examination had shown moderate inflammation adjacent to the tube in dog 14, and shortly before this time the dog had been observed to have slight stridor and cough when excited; no inflammation or abnormal secretion was observed in dog 15.

Dogs 16 and 17 died from mediastinitis a few days after surgical removal of their tubes, the tubes having been in place for ten and a half and eight and a half months, respectively. No resection of trachea had been carried out at the time of their first operation. The tube was merely inserted in the lower part of the trachea through a longitudinal

incision, and the incision was closed about the tube. The cause of mediastinitis was a leak where a suture used in closure of the trachea had cut through. In dog 17, however, an unsuccessful attempt had been made a week before the final operation to remove the tube through a cervical tracheotomy incision; the leak in this dog was from the cervical, not the thoracic, tracheotomy wound and may in part have been caused by trauma from introduction of the rigid metal intratracheal tube used to give the anesthetic for the last operation. The most abnormal bronchoscopic observations of the entire study were in these 2 dogs. At each examination the tubes appeared to fit loosely. No inflammation or abnormal secretion was seen in dog 16 two weeks and eight and a half months after operation; but at four and a half months

TABLE 3.—*Removal of Polythene Tube from Healed Trachea, in Dogs*

Dog	Segments Resected, Region	Bronchoscopic Examination, Months Post-operatively	Tube Removed, Months Post-operatively	Period Observed, Months	Disposition or Present Condition
14	5, neck	2	2.5	2.5	Died from asphyxia instantly after removal of tube
15	5, neck	1	1.5	1.5	
16	0, thorax*	0.5, 4.5, 8.5, 10	10.5	10.5	Died, mediastinitis, after removal of tube
17	0, thorax*	4, 8	8.5	8.5	
18	6, neck	1.5, 9, 11	9.5	13	Alive, well (tube replaced at 11 mo.)
19	5, neck	2	1	4	Alive, well
20	5, neck	1	1	3	Alive, well (tube replaced at 1 mo.)
21	0, right bronchus*	3, 7, 9	Coughed up	10.5	Alive, well (tube removed from neck at 7 mo.)
22	0, left bronchus*	2.5, 6.5, 8.5	Coughed up	10	Alive, well (tube absent at 6.5 mo.)

* Tube implanted in trachea or bronchus through a longitudinal incision, which was closed about the tube; no resection, however, was performed.

the surrounding portion of the trachea was slightly reddened and a small amount of mucus was retained behind the tube, and at ten months there was rather pronounced surrounding inflammation. The examination of dog 17 four months after operation showed moderate inflammation adjacent to the tube and a small accumulation of mucus in the distal portion of the trachea; at eight months, however, no inflammation or mucus was seen. About a month after the tubes had been implanted, dogs 16 and 17 manifested slight stridor and were observed to cough frequently when they were active. Further, or severer, respiratory abnormalities did not develop, however.

Dog 18 underwent resection of six segments of the lower cervical part of the trachea, and dogs 19 and 20 each underwent resection of five segments; all 3 dogs have had their original tubes removed, and

all are living. The tube was removed from dog 18 after it had been in place nine and a half months; before removal of the tube the dog had breathed normally and had not coughed, and bronchoscopy at one and a half and nine months had shown no inflammation or abnormal secretion in the trachea. Shortly before the next bronchoscopic examination severe stridor developed and the dog began to lose weight. Bronchoscopy disclosed collapse of the trachea at the site where the anastomosis had been made, and this observation was confirmed at operation when a new tube was implanted, one and a half months after the first tube had been removed. Since the second operation, the dog has been free from stridor and has gained weight.

The anastomosis tube was removed from dog 19 one month after it had been inserted. The dog was well and the trachea adjacent to the tube appeared normal. A month after the tube had been removed, bronchoscopy showed a tiny area of granulation tissue on one edge of the healed tracheotomy incision but no stricture or retained mucus. During the three months since removal of the tube the dog has remained well.

Dog 20 was observed, a few weeks after resection, to have stridor. This became severe rather rapidly. Bronchoscopy one month after operation showed that breathing became normal when the bronchoscope was passed beyond the tube. Therefore the trachea was opened, the first tube was removed, and a second, slightly longer tube was implanted. At this operation a short area of collapse of the anterior tracheal wall was seen at the distal end of the tube. The cause of collapse appeared to be that the tube was too short and too large in diameter. During the two months since replacement of the tube the dog has been free from stridor.

The remaining 2 dogs of this study, dogs 21 and 22, had polythene tubes implanted in the right and left main bronchus, respectively, through longitudinal incisions. No resection of bronchus was performed. In order not to obstruct the bronchus of the upper lobe an elliptic defect had to be cut in the distal end of each tube.

Bronchoscopy of dog 21 three months later showed that the tube had broken loose and was free in the midtrachea. It could not be extracted. There was only slight inflammation of the midtrachea; the dog appeared well and had no abnormal respiratory signs. After examination the dog continued to be so well that it was thought the tube had been coughed up. Four months later, seven months after operation, another bronchoscopic examination was made and, although the dog had no cough and was in excellent health, the tube was found lodged just distal to the larynx. After the tube had been removed with bronchoscopic forceps, slight inflammation of the first portion of the

trachea was observed. Another examination two months later showed normal trachea and bronchus.

Two and a half months after implantation the tube in dog 22 was observed to be firmly in place, although it appeared from the upper end to fit loosely. The bronchoscope could not be introduced through the tube. The dog remained well and was never observed to cough. The examination at six and a half months after operation, however, showed the tube to be absent. Slight deformity of the bronchus was seen, and a silk suture was removed from this region. Two months later the bronchus appeared normal.

REPORT OF A CASE

The patient, a man 49 years of age, registered on Jan. 16, 1941. In February 1938, bronchopneumonia, with a temperature of 104 F., had developed. This illness cleared in about a week, but the patient continued to cough occasionally, coughing up a small amount of blood. In June, he had been rather ill for several days, with a temperature of 101 F., general malaise and a severe productive cough. From June 1938 to June 1940, the patient had six similar attacks. Roentgenograms of the thorax were reported as showing no abnormalities on seven occasions. In August 1940, wheezing respiration developed. This gradually became worse and the dyspnea severer, until the patient was incapacitated for any effort. There had been a loss of 45 pounds (20.4 Kg.).

The results of physical examination were not remarkable except for the pronounced wheezing and labored respiration. A roentgenogram of the thorax on Jan. 23, 1941, showed no abnormalities. The results of all routine laboratory studies were negative. On January 20, bronchoscopy was performed by one of us (H. J. M.). The patient stopped breathing when the bronchoscope was introduced. The trachea and both bronchi were observed to be completely plugged by a huge tumor mass. This mass was removed piecemeal with bronchoscopic forceps, and artificial respiration was instituted. Gradually an airway was established and respiration was restored. Pathologic examination of the tissue that had been removed disclosed that the tumor was a cylindroma of the trachea. The patient was remarkably relieved by the bronchoscopic removal of the tumor. All wheezing and dyspnea disappeared. On January 27, bronchoscopy was repeated, and, with the mass of tumor removed, it became apparent that the tumor arose from the anterior wall of the trachea a little above the coryna. The infiltrating base of the lesion was burned by surgical diathermy. The patient was then referred for roentgen therapy of the lesion.

Between January 1941 and January 1947, bronchoscopy was repeated eight times to remove recurrent tumor encroaching on the tracheal airway. Roentgen therapy was repeated, but without apparent benefit. In spite of all conservative measures possible, the trachea continued to narrow gradually (fig. 3). On Aug. 22, 1946, there was a tracheal lumen at the site of the lesion of only 2 mm. This was dilated bronchoscopically, with some relief. Careful measurement disclosed that the distance from the larynx to the proximal margin of the tumor was 7.5 cm., and the distance from the distal edge of the tumor to the coryna was 3.5 cm.

On Jan. 20, 1947, the patient returned, complaining of severe wheezing and dyspnea. It was apparent that nothing further could be accomplished by

conservative means. After a complete and frank discussion of the risks involved the patient requested that an attempt be made to remove the tumor of the trachea by surgical means.

Anesthesia for operation presented a considerable problem, because the lumen of the trachea was so constricted that it did not seem likely that it would provide an adequate airway for anesthetization. It was decided that a bronchoscope should be inserted and forced through the narrowed trachea and that a general anesthetic agent should be given through the bronchoscope, After topical preparation of the pharynx with cocaine, a Negus bronchoscope was introduced and

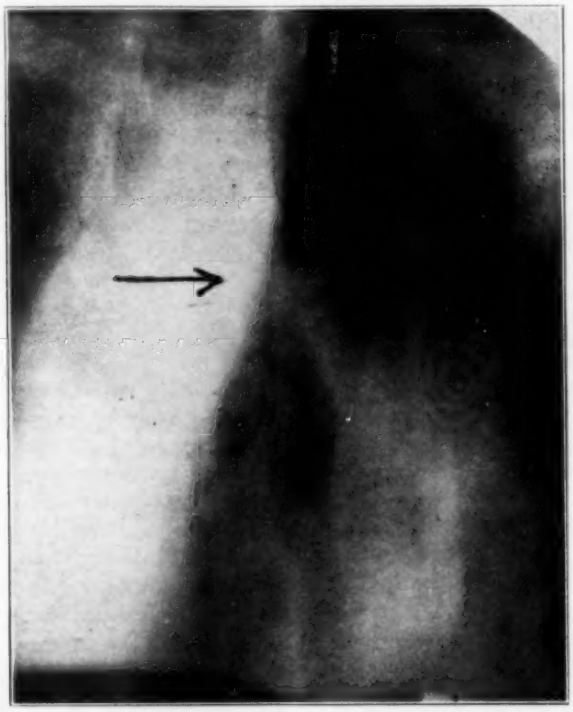

Fig. 3.—Tomogram of the trachea. The arrow points to the extreme narrowing at the region of constriction.

with some difficulty was passed beyond the strictured region and down into the left main bronchus. Nitrous oxide, oxygen and ether were then administered.

The surgical approach was made through a right posterolateral incision, the fourth and fifth ribs being resected. The trachea and tumor were dissected out without great difficulty and without the left pleural space being opened. A circular incision was made through the trachea above and below the tumor, thus completely freeing the segment of trachea containing the tumor. A polythene tube of suitable size and length was selected for insertion. Silk sutures were placed in the cut edges of the proximal and distal ends of the trachea, so that the ends could be brought as close together as possible after the tube had been inserted. When all preparations had been made, the bronchoscope was withdrawn from the left main bronchus and lower part of the trachea. The resected segment

of trachea was removed, the polythene tube was inserted to restore the tracheal defect and the bronchoscope was reinserted into the left main bronchus. This procedure took only a few seconds and caused no great difficulty. We then attempted to approximate the two tracheal ends over the tube as closely as possible with the interrupted silk sutures that had been placed previously. Unfortunately, the tissues at the lower end of the trachea were friable and weak and the tracheal tug accompanying respiration pulled the sutures out repeatedly.

It finally became obvious that it was not going to be possible to preserve the lower part of the trachea and coryna. Therefore, after reinsertion of the bronchoscope into the left main bronchus, right pneumonectomy and resection of the coryna were performed. A long polythene tube was made by telescoping a long but smaller diameter tube into a larger tube. The bronchoscope was again withdrawn from the left main bronchus and the larger end of the polythene tube was inserted into the trachea, the smaller end into the left main bronchus. Again the patient tolerated this maneuver remarkably well. The polythene tube fitted the trachea and bronchus snugly, and there was no leakage of air. Purse string sutures were used to hold the tube firmly in place. The mediastinal pleura was closed. The pleural space was irrigated with saline solution. Two hundred thousand units of penicillin were left in the right pleural space, and the thoracic wall was closed. All secretions were aspirated from the tracheobronchial tree before the bronchoscope was removed. Tracheotomy was then performed to facilitate aspiration from the tracheobronchial tree of any secretion that might develop subsequently. The patient was beginning to respond and was in excellent condition when he was returned to his room. He was placed in an oxygen tent immediately.

There was remarkably little reaction from the operation. The patient's color remained good. There was an elevation of temperature to only 100 to 101 F. for the first four days after operation. The patient was able to eat without difficulty and to talk when the tracheotomy tube was closed. There was a good deal of secretion in the tracheobronchial tree, which required frequent aspiration postoperatively. It was interesting to note that the patient never coughed voluntarily and he apparently was not conscious of the presence of any secretions that should be coughed up. The left lung was perfectly clear on roentgenographic examination until the third day, when patchy areas of bronchopneumonia appeared. In spite of massive doses of penicillin and frequent aspiration of the tracheobronchial tree the bronchopneumonia progressed, and on the sixth postoperative day the patient died of respiratory failure.

Postmortem examination revealed that the plastic tube was not properly placed. It partially blocked the left upper lobe bronchus and undoubtedly was responsible to some extent for the extensive bronchopneumonia present in the upper lobe of the left lung. There was no evidence of mediastinitis or of empyema in the right pleural space. No residual tumor was observed.

COMMENT

Previous experience in our laboratory had shown that tubes of various metals placed in the trachea became so coated with mucus that tracheal obstruction and death occurred. This experience would seem to increase the hazards and discourage consideration of a method of reestablishing continuity of the trachea by a tube of foreign material after resection. At the time when the study was undertaken, however,

we were using the plastic, polythene, in other studies.[3] We had learned that tubes of this material are not wetted by water, that clotting of blood or lymph within polythene tubes takes place very slowly and that mucus or other organic material does not seem to adhere to them. Moreover, it appeared that polythene, which is a polymerized form of ordinary paraffin and differs from the latter mainly in being insoluble in all solvents at room or body temperature and in being flexible and having great tensile strength, does not produce inflammatory or foreign body reaction in living tissue. We were encouraged, therefore, to make the tubes for anastomosis of the trachea of polythene. As far as we know, no other material now available would have sufficed for this purpose.

The death of dogs 1, 2 and 3 from defective tubes obstructing the trachea and producing asphyxia represents an accident that we feared when the method of making tubes was being developed and when the tubes used in these 3 dogs were made. No such accidents have occurred since it was learned what thickness of film to use for the wall of a tube, what thickness for ridges and how to fuse the layers into one mass. The death of dog 15 was accidental. It was thought that the tube had broken loose since the last bronchoscopic examination and had obstructed a main bronchus. In the attempt to find it there, the coryna was removed and the dog died of asphyxia at the close of the operation. All other deaths in this study have been, not because of the tube, but because the tube was removed. Dog 14 died of tracheal collapse immediately after the tube had been removed, and dogs 16 and 17 died, after their tubes had been removed, from infection caused by a leak from recent tracheotomy incisions.

Physical signs attributable to the presence of a tube and abnormal bronchoscopic observations were uncommon and were observed only in dogs in which the tube was defective or appeared to fit poorly. The tube was defective in manufacture, allowing it to collapse partly in dog 3, which had slight stridor and cough. In dog 14, with slight stridor and cough, and dog 20, with severe stridor, the tube was noted at operation to be too large in diameter and to fit very tightly. In dogs 16 and 17, both with slight stridor and cough, the tubes were probably too small in diameter. Other abnormal physical signs were seen only in

3. Grindlay.[2] Brown, M. H.; Grindlay, J. H., and Craig, W. McK.: Preliminary Report on Experimental and Clinical Studies with Polythene Film, Proc. Staff Meet., Mayo Clin. **22**:453-456 (Oct. 1) 1947; The Use of Polythene Film as a Dural Substitute: A Preliminary Report, J. Neurosurg. **4**:505-507 (Nov.) 1947; The Use of Polythene Film as a Dural Substitute: An Experimental and Clinical Study, Surg., Gynec. & Obst. **86**:663-668 (June) 1948. Grindlay, J. H., and Mann, F. C.: Surgical Uses of Polythene: An Experimental Study, to be published. Seybold, W. D.; Grindlay, J. H.; Pfuetze, K. H., and Clagett, O. T.: The Use of Polythene Film in Posterior Thoracoplasty Wounds, unpublished data.

dog 18 after the tube had been removed and collapse of the trachea had occurred at the site where fibrous tissue bridged the gap. The only abnormal bronchoscopic observations were in these dogs (dogs 3, 14, 16, 17 and 20), with the exception of the observation of slight inflammation in a few dogs examined a few weeks after operation.

The length of tracheal segment resected does not appear to be so important as the closeness of approximation of the ends of trachea over the tube. It was learned early in the study that the trachea possesses great elasticity and that a closely approximated end to end anastomosis could be made after as much as a quarter of its length had been removed. However, it seemed desirable to leave a gap, bridged by the anastomosis tube, in some dogs. For example, we wished to know whether cartilage formed in the tissue that grew about the tube to bridge the gap. The following dogs had gaps of various lengths: dog 1, 8 to 10 mm.; dog 2, 5 mm.; dog 6, 8 mm.; dog 14, 25 mm.; dog 18, 5 mm., and dog 19, 5 mm. The trachea was examined either at necropsy or at operation in each of these dogs and showed neither gross nor histologic evidence of presence of cartilage in the fibrous tissue. Lack of cartilage in the new tissue which bridged the gap was the cause of tracheal collapse which followed removal of the tubes in dogs 14 and 18.

The fact that, by about a month after operation, bronchoscopic examination usually showed no evidence of inflammation or retention of secretion and the fact that usually the bronchoscopist had some difficulty in seeing the semitransparent smooth tubes made us suspect that the tubes were surrounded by tracheal epithelium, and not by inflammatory tissue. Necropsy showed that the epithelium under the tube, including the surface of fibrous tissue gaps, was tracheal epithelium. Inflammatory cells, both leukocytes and lymphocytes, were, however, present in the epithelium as well as in the deeper layers of the wall. The finding of nonepithelized tracheal wall and excessive amounts of granulation tissue about a tube was limitied to experiments in which the tube itself was defective (dog 3) or in which the tube was too large or too small in diameter (dogs 14, 16, 17 and 20).

The experiments in which the tube was removed after healing of the anastomosis had occurred indicate that this may be done if the gap left between the ends of the trachea at the time of anastomosis is short and the tube fits well. Dog 19, in which the gap was only 5 mm. and the tube fitted properly, is the only dog which tolerated removal of the tube.

Implantation of a tube in the trachea or the bronchus, a procedure which might be considered in cases of stricture, tracheal collapse or nonresectable tumor, was performed in a few dogs. This limited experience indicates that such tubes are difficult to insert in dogs and that a tube small enough to be inserted is so small in diameter that it

rubs against the wall of the trachea and causes inflammatory reaction. Nevertheless, the 2 dogs (dogs 16 and 17) with tubes in the lower part of the trachea survived until the tubes were removed and died because of leakage from a tracheotomy wound. The 2 dogs with tubes implanted in a bronchus likewise indicate that the implanted tubes function and are tolerated. It is surprising that the tube in dog 21 was free in the trachea for four months and yet caused no physical signs and did not injure the trachea or interfere with drainage of bronchial secretions.

SUMMARY

Portions of the lower cervical or lower thoracic region of the trachea have been excised in a series of 18 dogs and continuity has been reestablished by anastomosis over molded polythene tubes. Molded polythene tubes were implanted surgically in the lower thoracic region of the trachea in 2 dogs and in the main bronchus in 2 dogs. Three dogs were killed at intervals after operation; 3 died of tracheal obstruction caused by defective anastomosis tubes, and 2 died of tracheal collapse after removal of tubes. Ten dogs that have undergone resection of the trachea were living at the time of writing and had no disturbance of the respiratory tract two and a half to thirteen months after operation. Two of these dogs had the original tubes replaced, while 1 had the tube removed and not replaced.

Molded polythene tubes were implanted surgically in the lower thoracic portion of the trachea in 2 dogs, both of which died of mediastinitis after removal of the tubes eight and a half and ten and a half months later. Tubes were implanted in a main bronchus in another 2 dogs, both of which are living after having lost their tubes.

Except in a few experiments, signs of disturbance of respiration have not been observed, and bronchoscopic examinations have shown no retention of tracheobronchial secretion and little, if any, inflammatory reaction.

A clinical case of cylindroma of the lower third of the trachea is reported, in which the patient died of bronchopneumonia on the sixth day after resection of a portion of the lower region of the trachea, pneumonectomy on the right side and anastomosis of the left bronchus to the trachea with a long two piece polythene tube.

INCARCERATED AND STRANGULATED INGUINAL HERNIA

Critical Survey of Five Hundred Consecutive Cases With Treatment by Nonsurgical (Taxis) and Surgical Procedures

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AND
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INCARCERATED or strangulated inguinal hernias are surgical emergencies and are usually an indication for immediate operation. Individual experiences and reports in the literature have emphasized the risk in delaying operation and the dangers incident to reduction. The pathologic changes in the hernia cannot be determined with complete certainty without exploration. However, for many years the practice at the Cook County Hospital has been to attempt to transform these situations from a surgical emergency to a later elective procedure. The routine procedure is the result of observations and experiences of Dr. Roger T. Vaughan. Accordingly, this survey of 500 cases of incarcerated or strangulated inguinal hernia was undertaken to determine the results of treatment as followed in this institution.

The advantage of an elective operation for a simple inguinal hernia is not to be disregarded if the method used for reduction of an incarcerated hernia is relatively safe. Almost all surgeons [1] have warned against blind reduction for strangulated hernias. Beller and Colp [2] expressed the belief that taxis is an inheritance from the days before antiseptic surgical procedures and is dangerous and unsatisfactory. Despite general surgical opinion to the contrary, it has been the practice at the Cook County Hospital to attempt, more or less routinely, manual reduction prior to operation. This study is an attempt to evaluate the

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2. Beller, A. J., and Colp, R.: Strangulated Hernia from Standpoint of Viability of Intestinal Contents: Report of Two Hundred and Seventy-Eight Cases, Arch. Surg. **12**:901-918 (April) 1926.

risk and dangers of manual reduction of incarcerated inguinal hernias when nonoperative and operative types of treatment are used.

MATERIAL STUDIED

During the years 1940 to 1947, inclusive, 500 patients with incarcerated or strangulated inguinal hernia were admitted to the Cook County Hospital. Incarcerated hernias are considered irreducible hernias with pain or obstructive symptoms. Symptomless irreducible hernias are not included in this study. Strangulated hernias are incarcerated hernias with impairment of the blood supply to the contained viscera by constriction at the neck of the sac; the diagnosis of strangulation usually is made with complete certainty only at operation. Prompt relief of the vascular obstruction is necessary to prevent necrosis or gangrene. Many clinically diagnosed strangulated hernias are found at operation to be incarcerated hernias with unimpaired circulation.

All uncomplicated incarcerated or strangulated hernias were subjected to attempts at manual reduction prior to operation. Manual reduction is not attempted if the hernia is exquisitely tender or inflamed. The hernias were divided into three series: (1) those reduced without operation, (2) those requiring operation and (3) those receiving no treatment because of the moribund condition of the patient or his refusal of operation.

ROUTINE TREATMENT

The manual procedure consists in placing the patient in a steep Trendelenburg position—vertical hanging in children—with gentle manipulation and diffuse pressure on the hernial mass. Successful reduction is evidenced by disappearance of the hernia and the absence of a mass in the lower quadrant of the abdomen. This is determined by palpating with one hand on the abdomen and with a finger of the other hand in the internal ring. Immediate relief of pain, return of bowel sounds toward normal and disappearance of nausea and vomiting occur. After a day or two of hospitalization elective herniotomy is performed, provided that oil and stool, but no blood, appear via the rectum.

Emergency surgical treatment was employed in those cases in which manual reduction proved unsuccessful or was contraindicated. Various surgical procedures were used, according to the judgment of the surgeon. In the majority of cases the hernia was reduced and repaired; in others a gangrenous bowel was resected or exteriorized. Primary resection with anastomosis is considered the procedure of choice. Spinal anesthesia was used in the majority of cases.

The viability of the bowel at operation is occasionally difficult to determine, and it is extremely important in borderline cases that several of the many tests which have been recommended be used. Resection

of a bowel capable of recovery increases the surgical risk; yet replacement of gangrenous bowel is fatal. Some surgeons have advised exteriorization of the bowel when the viability is questionable and replacing it within the abdomen at a later date if it proves to be viable. However, it is strongly recommended that a decision be made at the time of operation either to resect or to replace the bowel.

RESULTS

Reduction of the hernia without operation was accomplished in 298 patients, or 60 per cent of the series (table 1). There were 7 hospital deaths, a mortality rate of 2.4 per cent. One death was the direct result of manual reduction with the patient under morphine anesthesia; another

TABLE 1.—*Results of Treatment in 500 Consecutive Cases of Incarcerated and Strangulated Inguinal Hernias*

	Number of Cases	Number of Deaths	Mortality Rate, Percentage
Nonsurgical Treatment	298	7	2.4
Hernia reduced by			
Hanging posture only	34	0	0.0
Manipulation and posture	264	5	1.8
Surgical complication following reductions	10	2*	20.0
Surgical Treatment; Failure of Manual Reduction or Complication of Manipulations	205	33	16.8
No strangulation noted			
Operative reduction and simple repair	52	2	3.84
Strangulation diagnosed	148	31	20.9
Contents viable	123	13†	10.4
Contents gangrenous	22	18	72.0
Resection and primary anastomosis	18	13	72.2
Exteriorization of bowel	4	4	100.0
Drainage of inguinal abscess secondary to gangrenous bowel	3	1	33.3
Exploration after manual reduction for persistent symptoms	3	0	0.0
No Treatment. Patient admitted in shock, was dying or refused operation	7	6	85.7

* Both deaths followed operation.
† Included 2 cases of replacement of gangrenous bowel and 1 of bladder (surgical error).

was an operative death after hernial incarceration recurred. The other hospital deaths in this group were due to cardiovascular disease. In 10 of these cases of reduced hernia subsequent emergency operation was required. Four of the ten hernias recurred and became irreducible, and immediate operations were performed. Three of these hernias were reduced operatively and repaired, but in the fourth case there was questionable viability of the bowel and the loop was exteriorized. The patient died after the loop of bowel was called viable and was replaced in the abdomen. Four patients of the 10 continued to have obstructive symptoms after the hernia was reduced, and exploration was necessary. No cause for the symptoms could be observed in 1 case; in 1 case an adherent loop of bowel was freed from the sac, and in the third case there was diverticulitis of the sigmoid. All the patients recovered. The

fourth patient continued to have tenderness, pain and slight fever, but flatus and oil were passed freely. The significance of a palpable "sausage-shaped mass" at the internal ring was not recognized immediately. At operation a hernia reduced *en masse*, with a gangrenous bowel, was seen. The patient died. Two additional reductions *en masse* occurred, and both patients recovered after operation. In 1 the condition was recognized at the time of reduction, because of the palpable tumor at the internal ring, and in the other there was a preoperative diagnosis of appendicitis, because of recurrent abdominal symptoms.

Emergency operation was performed on 195 patients, or 40 per cent of the series, because the hernias proved irreducible, and also on the 10 patients who had complications of manual reduction. There were 33 deaths in these 205 patients, a mortality rate of 16.8 per cent. Surgical reduction with repair was done on 175 patients. Of these, in 123 patients the hernia was strangulated, but the bowel was considered

TABLE 2.—*Relation of Duration of Incarceration to Mortality Rate*

	Nonsurgical, Reduction		Surgical Treatment			
			No Strangulation		Strangulation	
Duration	Number of Cases	Mortality Rate, Percentage	Number of Cases	Mortality Rate, Percentage	Number of Cases	Mortality Rate, Percentage
1 to 6 hr.	91	0.0	8	0.0	14	0.0
6 to 24 hr.	108	1.8	24	0.0	44	11.3
24 to 72 hr.	35	2.8	15	6.6	30	20.0
3 to 6 days	32	6.2	17	5.8	31	38.7
7 to 14 days	8	0.0	2	0.0	16	31.2
14 to 21 days	2	0.0	0	0.0	0	0.0

viable and replaced within the abdomen. The 13 deaths in this group of 175 patients included 3 which resulted from replacement of nonviable organs: in 2 cases there was gangrenous bowel, and in the third there was focal necrosis of strangulated bladder wall, not recognized at operation, with retroperitoneal extravasation of urine confirmed by autopsy. At operation in 22 cases there was a gangrenous small bowel; resection with anastomosis was done in 18 cases, with 13 deaths, and exteriorization of the bowel in 4 cases, with 4 deaths. The mortality rate for the 22 cases of gangrene was 77 per cent. Incision and drainage of inguinal abscesses secondary to gangrenous bowel was necessary for 3 patients, and 1 died.

The duration of the incarceration of the hernia and the age of the patient contributed to causes of death. No deaths occurred in 113 cases, including 22 surgically treated patients with incarceration under six hours in duration (table 2). Only in the groups of cases with actual strangulation confirmed by operation was the mortality rate high. In

these cases with strangulation the rate increased from 11.3 per cent with incarceration of six to twenty-four hours' duration to a rate of 38.7 per cent with incarceration from three to six days. The rate also increased with advancing age and was highest in the eighth decade (table 3).

Shock ranked first as the most frequent cause of death after operation (table 4); 7 patients were admitted with a systolic blood pressure of 90 mm. or less and all died. The highest number of deaths occurred in the groups with the longest duration of incarceration and in the older age groups. Cardiovascular disease ranked second, as also would be

TABLE 3.—*Relation of Age to Mortality Rate*

Age, years	1-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
Number of cases	76	54	85	79	97	73	29	3
Number of deaths	0	1	3	8	14	16	2	0
Mortality rate (percentage)	0	1.9	3.5	10.1	14.4	21.9	6.9	0

TABLE 4.—*Causes of Death in 500 Consecutive Cases of Incarcerated and Strangulated Inguinal Hernia*

		Number
Shock		14
No operation or reduction, patient admitted in shock	5	
Postoperative	8	
Anesthetic (spinal)	1	
Cardiovascular Disease		12
Nonsurgical, manual reduction	4	
Postoperative	8	
Infection		8
Pneumonia	3	
Subphrenic abscess	1	
Peritonitis	4	
Exhaustion after enterostomy		1
Cause not determined (all deaths postoperative)		9
Total		44

expected, since 56 per cent of the patients were over 50 years of age and many were in poor general condition. Almost all the deaths occurred in patients over 50 years of age. In the group under 30 years there were no deaths, only 1 death under 40 years and only 4 under 50 years of age. It is significant that only 4 deaths were attributed to peritonitis. This may be accounted for by the use of chemotherapeutic agents and, more recently, the antibiotics.

COMMENT

In large charity hospitals an incarcerated or strangulated hernia constitutes one of the most important surgical emergencies. Reports of observations and experiences of most surgeons strongly emphasize the serious risk of delaying operation and the dangers of attempting manual

reduction when the pathologic condition present is clinically so uncertain. Alexander [3] expressed the belief that taxis or manual reduction was overdone and should not be taught in medical school. Wangensteen [4] stated that taxis is of "doubtful value unless the patient is seen within a short time." Coley [1b] considered five minutes as a time limit for efforts at reduction, while Power [1d] advised against using taxis if strangulation was over five hours in duration. There is no clinical means of determining whether actual strangulation exists. There exists no report in the literature statistically supporting these criticisms of treating incarcerated inguinal hernia by manual reduction followed by interval operation.

The object of manual reduction of incarcerated hernia is to transform a surgical emergency with a high rate mortality into an elective operation with a comparatively negligible rate of mortality. Attempts to reduce manually all noninflammatory incarcerated and strangulated inguinal hernias prior to operation has been followed for years at the Cook County Hospital under the experienced supervision of Dr. Roger T. Vaughan. In this series of 500 cases, two hundred and ninety-eight hernias, or 40 per cent, were so reduced. There were 7 hospital deaths; 1 was the direct result of manual reduction under morphine and 6 were due to other causes.

The danger of reducing gangrenous bowel into the peritoneal cavity has been one of the chief objections to manual reduction. This did not occur in our series and is probably more a theoretic than an actual danger. Such a hernia is usually too tender to tolerate manual pressure unless the patient is under the influence of a narcotic, and narcotics should never be used to facilitate taxis. Furthermore, gangrenous and inflamed bowel is adherent to the sac and its neck by an inflammatory exudate which prevents reduction save by excessive violence.

Unrecognized reduction *en masse* is a more real danger. This occurred in 3 of our reported cases; in 1 case the condition was unrecognized, and the patient died. In the other 2 cases the condition was recognized and the patients recovered after operation. The continuance of the ileus and the presence of a palpable firm sausage-shaped mass inside the internal ring is evidence of this complication and should be sought for carefully. Immediate relief of pain and vomiting follows successful hernial reduction. The patient can at once ingest water and liquid petrolatum without nausea or vomiting. The peristaltic sounds also begin to return toward normal character.

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3. Alexander, E. G.: Report of One Hundred and Five Cases of Strangulated Hernia, Ann. Surg. **58**:639-646, 1913.

4. Wangensteen, O. W.: Intestinal Obstructions, Springfield, Ill., Charles C Thomas, Publisher, 1945.

Emergency operation was performed on 205 patients with acutely incarcerated or strangulated lesions, with 33 deaths, a mortality rate of 16.8 per cent. Most of these patients had had unsuccessful attempts at manual reduction, which may or may not have contributed to the higher mortality rate of our series as compared with the mortality rates reported by some other surgeons. In other similar reports the mortality rates were: Frankau (1931),[5] 654 cases with a mortality rate of 13 per cent; Douglas (1942),[6] 34 cases with a mortality rate of 9 per cent; Beller and Colp (1926),[2] 133 cases with a mortality rate of 11 per cent; Alexander (1913),[3] 60 cases with a mortality rate of 27 per cent; Erdmann (1904),[1a] 31 cases with a mortality rate of 16 per cent, and Eliason and Welty (1947),[7] 41 cases with a mortality rate of 5 per cent. Our mortality rate for the surgically treated patients at least was not increased greatly by preoperative taxis. However, mortality rates in large charity hospitals may be higher because disease is more advanced or neglected before admission than is the case in private practice; also, mortality increases with age, as shown in table 3, and 56 per cent of our patients were more than 50 years old. A series dealing with younger patients would show a lower mortality rate, e. g., in our series there was only 1 fatality in the group under 40 years of age.

Some controversy exists among surgeons in regard to the best method of treatment of gangrenous bowel. Geist,[8] in 1933, expressed the belief that the mortality rate of primary resection was so high that only exteriorization and enterostomy should be done. Hay,[9] likewise, expressed the opinion that a multiple stage procedure was best. Waugh [10] recommended exteriorization and enterostomy in patients who were poor risks. Jarboe and Pratt,[11] however, advised resection and primary anastomosis in all cases when the viability is not known. Beller and Colp [2] found enterostomy undesirable and usually fatal. Erdmann,[1a] as early as 1904, expressed the belief that the risk of an exhausting

5. Frankau, C.: Strangulated Hernia: A Review of 1,487 Cases, Brit. J. Surg. **19**:176-191 (Oct.) 1931.

6. Douglas, D. M.: Strangulated Hernia—A Consideration of Some Factors Affecting the Mortality, Brit. M. J. **1**:354-357 (March 14) 1942.

7. Eliason, E. L., and Welty, R. F.: A Ten Year Survey of Intestinal Obstruction, Ann. Surg. **125**:57-65 (Jan.) 1947.

8. Geist, G. A.: Strangulated Hernia, Minnesota Med. **17**:143-145 (March) 1933.

9. Hay, A. W. S.: Strangulated Hernia with Gangrenous Bowel Treated by Multi-Stage Operation, Canad. M. A. J. **48**:46-48 (Jan.) 1943.

10. Waugh, J. M., in discussion on Clagett, O. T.: Strangulated Hernia in the Aged, Proc. Staff Meet., Mayo Clin. **14**:797 (Dec. 13) 1939.

11. Jarboe, J. P., and Pratt, J. W.: Strangulated Femoral Hernia: Surgical Management, Surg., Gynec. & Obst. **85**:185-194 (Aug.) 1947.

intestinal fistula was much greater than the extra time required for resection.

Resection and primary anastomosis for gangrenous small bowel has given better results than the exteriorization procedure, although the mortality rate for our resections was 72 per cent. Jarboe and Pratt had a mortality rate of 92.5 per cent for sixteen primary resections, Frankau 47 per cent for thirty resections and Hay 100 per cent for six resections. The time required for resection and anastomosis is not long, and in present day surgical practice, with the availability of whole blood and antibiotics, primary resection is the best treatment for gangrenous bowel.

Exteriorization of the involved bowel has been recommended for patients who are exceptionally poor surgical risks or when the viability of the bowel is questionable. In our series, 4 patients had loops of bowel exteriorized and all died. Three of these patients were poor surgical risks, and this accounted for the choice of operative procedure. However, it is believed generally that any operation which leaves the patient with an enterostomy opening should not be performed and further weakens a patient already critically ill.

Spinal anesthesia was employed by choice in the majority of cases. Inhalation anesthesia was used in 22 per cent of the cases and local infiltration with procaine in 11 per cent. In the latter group the patients were extremely poor surgical risks.

SUMMARY

A study of 500 consecutive patients with incarcerated and strangulated inguinal hernias admitted to an institution in which manual reduction is more or less routinely attempted prior to operation is reported in an effort to determine the dangers incident to manual reduction of hernias prior to operative treatment. This series includes patients admitted to the Cook County Hospital from 1940 to 1947 because of an acutely irreducible or obstructed hernia which caused pain, usually together with vomiting, distention and obstipation.

There were 298 cases in which manual reduction was employed, with 7 hospital deaths, a mortality rate of 2.4 per cent. One of these deaths was the direct result of manual reduction under morphine anesthesia, the remainder being from other causes. Ten of these reduced hernias required subsequent emergency operations. Four of these were hernias which recurred while the patients were awaiting interval operation, became irreducible and were operated on. Four patients continued to have symptoms after reduction and necessitated exploration. There was 1 death, a case of reduction *en masse*. This was the single death noted previously from manual reduction. Two additional hernias were reduced *en masse*, but both were promptly recognized, operation was performed and both patients recovered.

The principal hazard in the nonoperative treatment of incarcerated hernias in our series appears to be reduction *en masse*. Palpation of a mass just inside the internal ring is indicative of this complication and should be sought for carefully. Unsuccessful reduction is further indicated by failure to relieve the symptoms of obstructive ileus and pain.

Emergency operation was performed on 205 patients, or 40 per cent of the series, with 33 deaths, a mortality rate of 16.8 per cent. The operative procedure was simple reduction and repair in 175 cases, with 13 deaths. Three of these deaths resulted from replacement of nonviable organs. Gangrenous small bowel was seen at operation in 22 patients. In 18 cases the bowel was resected with primary anastomosis. There were 13 deaths, a mortality rate of 72 per cent. Exteriorization of the bowel was performed in the remaining 4 patients, and all died. Resection and primary anastomosis is considered the best treatment for gangrenous bowel.

SUMMARY AND CONCLUSIONS

A critical survey was made of 500 consecutive patients with acutely incarcerated or strangulated inguinal hernias treated with manual reduction, i. e., taxis and surgical procedures.

The mortality rate for the entire series of 500 patients was 8.8 per cent, and emergency operation was avoided for 288 patients, or 60 per cent.

Emergency operation was required for 205 patients, or 40 per cent of the series, with 33 deaths, a mortality rate of 16.8 per cent. One of these deaths was a direct result of the manual reduction (reduction *en masse*).

Manual reduction was accomplished in 298 cases, or 60 per cent of the series. Complications in 10 cases followed reduction and required emergency operation. There was a total of 7 deaths in this series, a mortality rate of 2.4 per cent, including 2 deaths which followed operation.

The mortality rate of 16.8 per cent reported here for the 205 patients subjected to emergency operation is higher than that of some surgeons and might or might not be due to manual manipulation prior to operation. However, mortality rates in large charity hospitals are likely to run higher because disease is more advanced or neglected on admission. Over half of our patients were more than 50 years of age, and almost all of the deaths were of patients over 50 years; only 4 of the 44 deaths were of patients under 50 years of age.

ANASTOMOSIS OF THE ILEUM TO THE LOWER PART OF THE RECTUM AND ANUS

A Report on Experiences With Ileorectostomy and Ileoproctostomy, With Special Reference to Polyposis

R. RUSSELL BEST, M.D.
OMAHA

IN 1901, Lilienthal [1] extirpated the colon following ileosigmoidostomy in a young woman for polyposis of the colon. Although rectal polyps were palpable, he did not treat them. Since then, the treatment for polyposis of the colon has developed to where now the accepted treatment is fulguration of the polyps in the rectum and lower part of the sigmoid, followed by ileosigmoidostomy and colectomy. However, in a fair number of such patients, cancer has been reported to have developed subsequently in this rectal segment where the macroscopic polyps or adenomas had been destroyed by fulguration or coagulation. In other words, this disease, which is preponderantly familial, has a genetic predisposition to form polyps in the colon and rectal mucosa, and such activity tends to continue after destruction of the visible small tumor masses, with these new polyps being prone to malignant degeneration. Previous to 1941, I had observed the development of rectal carcinoma in 2 patients who had been treated by rectal fulguration, ileosigmoidostomy and colectomy. One of these patients had been treated elsewhere, and 1 had been treated by me. About this time, a man 43 years of age and his 18 year old son came under my care for polyposis of the colon. Both patients had rectal carcinoma and other carcinomas of the upper part of the colon. Complete colectomy and permanent ileostomy appeared to be the only procedure indicated.

Considerable thought was given to developing an operative procedure which might eliminate the need for a permanent ileostomy. In 1928, Stone [2] had recommended interposition of a loop of ileum to repair

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Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 21, 1948.

1. Lilienthal H.: Hyperplastic Colitis: Extirpation of the Entire Colon, the Upper Portion of the Sigmoid Flexture and Four Inches of the Ileum, Am. Med. **1**:164-165, 1901.

2. Stone, H. B.: Interposition of a Loop of Ileum to Repair Defects in the Colon, Ann. Surg. **88**:593-596, 1928.

defects of the lower part of the sigmoid. This did not appear applicable to malignant lesions of the middle part of the rectum. Since to avoid ileostomy it seemed desirable to remove not only the rectal carcinoma but also as much as possible of the rectum which was prone to further polyp development, it was decided to attempt low anastomosis of the ileum to the lower part of the rectum or anus.

During 1941 and early 1942, seven attempts were made to accomplish these low anastomoses. The study was interrupted by the war, and in 1945 and 1946 two additional attempts were made.

This paper is a report on the personal experiences with anastomosis of the terminal ileum to the lower 10 cm. (4 inches) of the rectum or directly to the anus. I must say that I cannot make a very optimistic evaluation of the procedure at the present time, and this I believe is the most important reason for citing the experiences and results of this study. Further improvements in technic and time may alter this view. In this series, the operation was done in 5 cases of polyposis with associated malignant degeneration of the rectum and in an additional 4 cases of advanced carcinoma of the rectum without polyposis.

Theoretically, the operation of anastomosing the ileum to the lower part of the rectum or anus could be physiologically successful in view of the fact that not infrequently the discharge from an ileostomy becomes semisolid and the patient finally assumes a normal fluid and nutritional balance. To control the timing of the expulsion of ileal contents with a functioning anal sphincter mechanism would seem possible and ideal.

Several French surgeons have continued to experiment with transplanting sections of the ileum between sigmoid and rectum. Quenu in 1933 [3] reported a successful ileocolic-plastic procedure in a case of carcinoma of the lower part of the sigmoid. Okinczyc in 1935 [4] reported in the French literature his 2 cases in which the transplant was brought down to the anus. In 1939, Picot [5] reported his case of ileal graft. In 1944 and 1945, the reports of Rudler [6] were made before the French Academy on his rather complicated procedure of isolating a section of ileum, doubling it on itself and by longitudinal division and anastomosis forming a pouch which was then transplanted between the rectum and sigmoid. A study of these cases from the French literature reveals that

3. Quenu, J.: Un cas d'ileo-coloplastie, Bull. et mém. Soc. nat. de chir. **59**:856-863, 1933.

4. Okinczyc, J.: Ileo-colo-recto-plastie, Bull. et mém. Soc. nat. de chir. **61**: 53-60, 1935.

5. Picot, M.: Ileocoloplastie apres resection rectosigmoidienne, Mém. Acad. de chir. **65**:874-879, 1939.

6. Rudler, J. C.: Un cas d'ileo-colo-rectoplastie, Mém. Acad. de chir. **71**: 124-126, 1945.

although several cases were rather successful, there were attending complications and problems.

It has been difficult to find case presentations in the literature wherein the ileum has been directly anastomosed to the last 2 or 3 inches (5 or 25 cm.) of the rectum or directly to the anus. Recently Ravitch and Sabiston [7] reported their experiments on dogs, in which the ileum was pulled through the anus and anastomosed to the sphincter muscle and skin. They suggested this procedure might prove a feasible method of avoiding a permanent abdominal ileostomy in patients requiring total colectomy for benign lesions.

Following are the résumés of the 9 cases in this series.

GROUP I. POLYPOSIS WITH CARCINOMA OF THE RECTUM AND ADDITIONAL CARCINOMA OF THE COLON: REPORT OF CASES

CASE 1.—D. F., aged 43, had polyposis and carcinoma of the rectum at the 10 cm. (4 inch) level, and also carcinomas of the cecum, transverse colon and descending colon. The polyps were coagulated in January 1941. Ileorectostomy was accomplished at the 3 inch (7.5 cm.) level, followed by right and left colectomy. He had good sphincter control and three to five stools daily. He died twenty-three months later, when carcinoma developed or recurred near the site of anastomosis and perforated and an abscess dissected upward in the abdomen and ruptured.

CASE 2.—L. F., aged 18, son of D. F., had polyposis and carcinoma of the rectum at the 10 cm. (4 inch level), with two additional lesions in the transverse colon. Coagulation of the rectal polyps was performed in 1941, followed by ileorectostomy at the 2 inch (5 cm.) level and colectomy. He had good control, with four to six stools daily. He lived twenty-two months and died apparently of carcinomatosis.

CASE 3.—F. R., aged 54, had polyposis limited to the rectum and two malignant lesions in the rectum, the lowest at the 3 inch (7.5 cm.) level. The polyps were coagulated in 1941, and then ileorectostomy was performed. The colon was not removed. Pelvic abscess and stricture of the anastomosis developed. A posterior sacral and anterior abdominal wall fistula developed. In November 1942, the ileum was anastomosed to the cecum, leaving the patient with a permanent colostomy. He was still living and working at the time of writing.

CASE 4.—Mr. G., aged 51, had polyposis and rectal carcinoma at the 4½ inch (11 cm.) level. The polyps were coagulated in 1945, and ileorectostomy and colectomy were then accomplished. A posterior sinus persisted for seven months. Stools averaged five per day. He was still living and well at the time of writing.

CASE 5.—Mr. B., aged 40, had polyposis and carcinoma of the rectum at the 5 inch level (12.5 cm.) and malignant lesions of the transverse and descending aspects of the colon. Fulguration of the polyps was done in 1946, followed by ileorectostomy at the 3 inch (7.5 cm.) level and colectomy. A posterior draining sinus and stricture developed, requiring ileostomy four months after the ileorectostomy. Carcinomatosis developed about twelve months later, and the patient died of intestinal obstruction.

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7. Ravitch, M. M., and Sabiston, D. C., Jr.: Anal Ileostomy with Preservation of the Sphincter (Proposed Procedure), Surg., Gynec. & Obst. **84**:1095-1099, 1947.

GROUP II. CARCINOMA OF RECTUM WITHOUT POLYPOSIS: REPORT OF CASES

CASE 1.—Mrs. Q., aged 55, had a large carcinoma of the rectum with the lower margin 2 inches (5 cm.) from the anal canal. In 1941, the rectum and sigmoid were resected and the ileum anastomosed to the anus and sphincter muscle by a combined abdominal and posterior approach (ileoproctostomy). The glands with metastasis were removed in this case. The sigmoid stump was left in the abdominal wall as a small mucous fistula of the colon. Stools averaged six to eighteen daily, but after several months of a constipating regimen the stools decreased to four to six daily. The patient was living and well at the time of writing.

CASE 2.—Mr. B., aged 49, had carcinoma of the rectum, with the lower margin at the 5 inch (12.5 cm.) level; operation revealed a large infiltrating mass below and at the rectosigmoid level. Ileorectostomy was accomplished at the 3 inch (7.5 cm.) level in December 1941. The stump of the short sigmoid was left as a small fistulous tract in the abdominal wall. The patient had ten to twelve loose stools daily for one month, and then the stools decreased to four to six daily. He died eight months later. Details of his death are unknown, but presumably it was due to carcinomatosis.

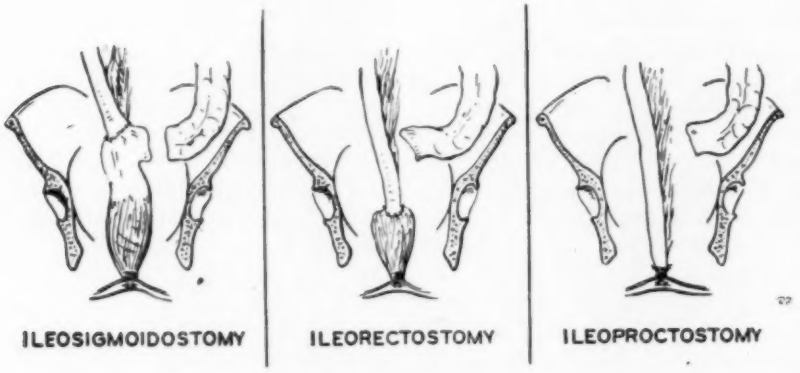
CASE 3.—Mrs. P., aged 62, had carcinoma of the rectum, with the lower margin 2½ inches (6 cm.) from the anal margin. Ileoproctostomy was accomplished at the sphincter level in January 1942, by abdominal dissection and posterior anastomosis after removal of the coccyx. A posterior draining sinus and rectovaginal fistula developed. Four months later, the lower part of the ileum was again divided and the proximal end anastomosed to the cecum, giving the patient a functioning colostomy. She died seven months after the first operation, from extensive metastasis.

CASE 4.—Mrs. P., aged 53, had carcinoma of the rectum at the 3 inch (7.5 cm.) level. At operation, in January 1942, the lesion was observed to be extensive. Ileoproctostomy was accomplished at the sphincter level by abdominal dissection and posterior anastomosis after removal of the coccyx. A severe posterior fistula developed, with decided excoriation of skin over the buttocks and lower sacral region. The patient was having six to seven stools daily. Six months later, the ileum was transected and the proximal end anastomosed to the cecum, leaving the patient with a functioning colostomy. She died eleven months after the first operation, from a cerebral accident.

TECHNICAL PHASES

Anastomosing the ileum to the last 2 to 4 inches (5 to 10 cm.) of the rectum or directly to the anus is a much more difficult procedure than anastomosing the ileum to the middle or lower part of the sigmoid. In cases of polyposis, the rectal polyps are first destroyed by fulguration to the region of the malignant growth or as high as possible. After the abdomen is opened, the peritoneum on the floor of the pelvis along the mesosigmoid is incised. The superior hemorrhoidal vessels are ligated and the rectum freed from the hollow of the sacrum and from structures laterally and anteriorly. If the lesion is at the 3½ inch (9 cm.) level or above, it is usually possible to complete the anastomosis from within the abdomen. The terminal aspect of the ileum is then surveyed and the

proper site chosen to enable the ileum to be delivered into the lower true pelvis. This site varies, because of the different formations of vascular arches and length of vessels. The ileum is divided at an angle, and the distal end is properly closed and invaginated. A sterile rectal tube is slipped into the proximal ileum and secured with several heavy sutures of surgical gut. The rectum is transected at least 1 inch (2.5 cm.) below the malignant growth, the lower end of the rectum being left open and controlled by several curved clamps or Allis forceps. The rectal tube with attached ileum is then placed into the jaws of a curved clamp which has been inserted into the anal canal by an assistant. Pulling on the tube permits the ileum to be telescoped into the rectal stump and several silk sutures placed. Further pull on the rectal tube invaginates the margin of the rectum, and anastomosis is completed with a layer of interrupted silk mattress sutures. The peritoneum of the pelvic floor is



Types of anastomoses.

approximated around the ileum. The tumor of the rectum with part of the sigmoid is excised and the stump of sigmoid brought out through a small stab wound to the left of the abdominal incision. In all of these cases, the patient was turned on his side and a small incision made along the coccyx. A drain which had been placed in the hollow of the sacrum before the pelvic floor was closed was pulled out through this incision. In cases of polyposis the colon is removed in one or two stages some weeks or months later. In cases in which polyposis was not present and the anastomosis had been made because it was impossible to bring the sigmoid and rectum into apposition, the stoma of the sigmoid or descending colon serves as a permanent mucus-draining site for the colon. After about two weeks, there is minimal discharge from the fistulous opening.

In three instances, the operation was done by combined abdominal dissection and posterior anastomosis. The pelvic structures were prepared as for an abdominoperineal excision. The sigmoid was divided

and the distal stump closed and pushed into the hollow of the sacrum. The proximal end was brought out on the abdomen to serve as a mucus fistula. The terminal ileum was prepared as previously described except that both ends were closed. The closed proximal ileum was then laid into the hollow of the sacrum. After the abdomen was closed the patient was turned on his side, the coccyx was excised, the rectum with the tumor and sigmoidal stump were removed, the ileum was opened and telescoped into the rectal or anal stump by means of a rectal tube and anastomosis was completed.

COMPLICATIONS

In this group of 9 cases, I experienced some difficult problems in postoperative management. Control of frequent loose stools required the free use of paregoric, milk of bismuth and tannic acid products. In over half of the cases, troublesome drainage developed posteriorly. The local cutaneous reaction was severe in 2 cases because of the digestive action of the small bowel contents. In 1 of these 2 cases, a rectovaginal fistula also developed. In these 2 cases and in another case in which a stricture developed, it became necessary later to divide the ileum and anastomose the proximal end to the cecum. The proximal sigmoid stump which had been acting as a mucus fistula for the blind colon then became a functioning colostomy. In 1 case of polyposis with rectal and colon carcinomas, it became necessary to resort to an ileostomy, because of a stubborn posterior fistula and stricture development at the site of the low anastomosis.

Sphincter control was not a problem in these cases. The urgency of stool in the early postoperative period was caused by the irritating effect of the digestive liquids on the lower rectal and anal mucosa. This usually subsided within three weeks, unless a troublesome posterior fistula was present. The drainage at the site of the posterior incision, resulting from a leak at the suture line, gave rise to the most troublesome problems. The digestive power of the small bowel contents was most difficult to control in this area.

Plasma protein studies were made of 4 of these patients and compared with those of 4 other patients, operated on at approximately the same time, for whom only a colostomy was done as the result of a radical abdominoperineal resection. During the first three weeks postoperatively, in the patients with ileorectostomy the plasma proteins averaged 5.2 Gm. and in the patients with colostomy the level of plasma proteins averaged 5.9 Gm. In the patients with troublesome posterior fistulas, it was most difficult to keep the plasma proteins up to a reasonable level. When the posterior drainage diminished or ceased, there was an immediate rise in the plasma protein level. As compared with the levels in 2 cases of elective ileostomy, the plasma protein levels were about the same

except for the period when the posterior fistula was draining severely. At these times, it was almost impossible to keep the plasma protein level above 5 Gm. Experiences of the last two years with 2 cases of ileorectostomy and several cases of ileostomy reveal less difficulty in keeping the serum protein level up with the use of protein hydrolysate products orally and parenterally. Nevertheless, when a draining fistula develops in any and all circumstances, a proper serum protein level is difficult to maintain and it appears most necessary to use plasma and whole blood to supplement the high protein diet and protein hydrolysates. It is now my practice always to supplement parenterally and orally administered protein hydrolysates with plasma or whole blood when the serum proteins need a definite boost. Evidently it is the natural quality and type of proteins found in plasma, and especially in whole blood, and not entirely the quantity in grams of protein that replace or stimulate a protein adequacy.

RESULTS

There were no operative deaths in this group of 9 cases. Four of the 5 patients with polyposis had carcinomas of the colon in addition to a rectal carcinoma. The fifth patient had polyposis limited to the rectum and sigmoid, and two carcinomatous lesions had developed in the rectum. The 4 patients with rectal carcinoma had extensive lesions, all bordering on the line of resectability. In fact, they were chosen for this procedure because in any event the prognosis did not appear good and they were patients who particularly pleaded against a permanent colostomy.

Results in This Series

Survival Period, Yr. (Approximate)	Patients	Results of Ileorectostomy	
		Satisfactory	Unsatisfactory*
1	4	1	3
2	3	2	1†
5 to 6	2	1†	1†

* Unsatisfactory means colostomy or ileostomy necessary later.
† Living and well as of the time of writing.

Of the 5 patients with polyposis and carcinoma, 1 lived twenty-three months, 1 twenty-two months and another twelve months, and all of them had recurrences of the malignant condition. Two patients were living and well at the time of writing; 1 had lived six years, this being the patient in whom a pelvic abscess and stricture developed which later required anastomosis of the ileum to the cecum. The permanent colostomy was possible because the polyposis had been limited to the rectum and a colectomy was not indicated. The other patient was living two years following operation; stools averaged three to four per day, with usually one evacuation at night. Of the 4 patients in group 2, with

extensive carcinoma of the rectum not associated with polyposis, 3 died within the first year. One of these required an anastomosis of the ileum to the cecum and a permanent colostomy four months after the ileorectostomy, because of a stubborn posterior draining sinus and recto-vaginal fistula. The fourth patient, operated on in 1941, was living and well at the time of writing and had four to six stools daily. Of the 7 patients operated on more than five years prior to reporting, only 2, or 28.5 per cent, were living at the time of writing and only 1 of these had a satisfactory ileorectostomy. Of the 2 patients operated on only two years prior to reporting, 1 was living and had a satisfactory ileorectostomy. An analysis of stool frequency and control reveals that immediately following ileorectectomy stools tended to occur eight to fifteen times daily, but with proper and adequate use of milk of bismuth and paregoric, tannic acid products and a constipating diet, the stool frequency was reduced to three to six times daily except when a complicating posterior fistula developed.

Because it was necessary to open the abdomen in 4 cases at some time following ileorectostomy or ileoproctostomy, there was an opportunity to make direct examination of the terminal ileal segment which had been anastomosed to the rectum or anus. In all instances, it was observed that the terminal ileal segment was dilated to about twice normal size and the wall was hypertrophied for a distance of about 10 to 12 inches (25 to 30 cm.). It can be assumed that as the terminal aspect of the ileum dilated, it gradually assumed the functions of absorbing liquid contents and the temporary storage of fecal residue, thus resulting in fewer evacuations.

CONCLUSIONS

1. The chief indications for anastomosing the terminal aspect of the ileum to the lower part of the rectum or anus are polyposis of the colon and the rectum, when carcinoma has developed in the rectum, and the patient's desire to avoid an ileostomy. Whether or not this procedure will give as many permanent cures as radical abdominoperineal excision with ileostomy cannot be definitely stated at this time. Statements for or against at this time cannot be predicated on comparative figures and experiences. One might set forth the argument that all early operations for carcinoma of the rectum were sphincter-saving procedures and the end results were very poor as compared with those in the later accepted procedure of radical abdominoperineal excision and colostomy. However, one must not forget that during these years when this latter operation has given the best results there has been decided improvement in technic, better preoperative and postoperative treatment and the advent of antibiotics. If the operation should be complicated by development of a stubborn fistula or stricture, an ileostomy can be established later.

2. At the present time, I do not believe that ileorectostomy or ileoproctostomy should be attempted in routine cases of rectal carcinoma in order to preserve the sphincter mechanism when it is impossible to bring the sigmoid and rectum into apposition. From the complications which appeared in these cases, a colostomy should be chosen in preference to attempting to preserve the sphincter mechanism by side tracking the colon and hooking the terminal ileum into the lower part of the rectum or anus until further refinements of technic have been developed.

3. Improvements in technic are wanting, but, from these experiences, the best operation at present appears to be a telescoping procedure, whereby a rectal tube is fixed into the ileum and the tube drawn out through the anus. Interrupted sutures complete the anastomosis. This may be accomplished entirely from within the abodmen or by a combined method of abdominal dissection and posterior anastomosis (described in a previous paragraph).

4. Because of the incidence of rather excessive posterior drainage or development of fistula, establishment of posterior drainage of the presacral space is indicated. In my opinion, the mortality rate would have been rather high if this had not been done. There was no operative death in this series of 9 cases.

5. Considerable effort must be directed toward decreasing the frequency of bowel movements during the early postoperative period. This has required the energetic use of paregoric and milk of bismuth and tannic acid products. A low residue constipating diet is of assistance. After several weeks, bowel movement frequency usually stabilizes itself at about three to six stools during the twenty-four hours, unless a complicating stubborn posterior fistula or stricture develops, resulting in almost constant posterior drainage.

6. Hypoproteinemia is rather pronounced during the early weeks postoperatively, but a normal level usually establishes itself after some three to four weeks. Efforts must be directed toward a high protein intake.

7. When the distal part of the ileum is anastomosed to the terminal part of the rectum or anus, it becomes dilated, the wall hypertrophies and its absorption function and storage capacity apparently increase.

8. Improvements in technic to afford better security of the line of anastomosis are desirable. This would result in fewer of the complications which seem to be the present drawback of the operation. With fewer complications, ileorectostomy and ileoproctostomy would have a wider field of usefulness and might serve as a means of preserving the sphincter mechanism in cases of polyposis, some cases of malignant degeneration of the rectum and ulcerative colitis.

DISCUSSION

DR. WALTER G. MADDOCK, Chicago: I would like to have Dr. Best tell us the reasons for having to do colostomies or ileostomies after having done a low anastomosis.

DR. R. RUSSELL BEST, Omaha: The chief reason was the development of a fistula; in other words, the anastomosis was not secure enough when I hooked the ileum into the power part of the rectum or anus. Fistulas developed in 4 out of 9 cases, and I had to do a colostomy or ileostomy because of the development of fistula. In 1 case a stricture developed, and I did an ileostomy. I believe that the incidence of fistula decreases with experience. Possibly a two stage procedure is indicated.

ENDOMETRIOSIS IN GENERAL ABDOMINAL SURGERY

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THE TREMENDOUS increase in the incidence of pelvic endometriosis during the last few years, together with the protean manifestations of the disease, make it of interest not only to the gynecologist but to the general abdominal surgeon as well. Since the days of Sampson's illuminating studies, more and more cases of endometriosis have been encountered on the gynecologic services of university hospitals, until today the disease is discovered to some degree in roughly half the patients subjected to abdominopelvic operation. It is my opinion that this increased incidence is not merely an apparent increase, resulting from a more critical evaluation of this much discussed disease, but is a real one. There has been much conjecture as to the cause of this increased incidence. More intrauterine and cervical instrumentation, particularly curettage, tubal insufflation and cervical cautery, with subsequent stenosis, are thought to be important factors. Perhaps the decreased frequency of gonorrheal salpingitis, with resulting tubal patency, is another cause. Any discussion of the causes for the increased incidence of endometriosis must include a more fundamental consideration of the cause of the disease, a consideration beyond the scope of this short paper. Whatever the reasons, the increased incidence of pelvic endometriosis now places it among the foremost diseases affecting women of the child-bearing age.

It is obvious at once that any one performing abdominal operations in women should have a thorough understanding of the signs and symptoms of this common disease, both in its usual manifestations and in some of its more bizarre forms where confusing but important problems in differential diagnosis may arise. It is the purpose of this presentation to point out some of the diagnostic features of endometriosis as it is encountered on the gynecologic service, with special emphasis on some of its more unusual and confusing aspects. The principles and details of treatment are a separate consideration, again too lengthy for the present discussion.

The symptoms of endometriosis depend to some degree on the distribution of the pathologic changes in the pelvic viscera and related struc-

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Read at the fifth annual meeting of the Central Surgical Association, Chicago, Feb. 19, 1948.

From the Department of Obstetrics and Gynecology, Northwestern Medical School, Chicago.

tures, but in general can be grouped under the headings of menstrual disorders, pain and infertility. The menstrual disorders encountered are varied, with menorrhagia or hypermenorrhea as perhaps the outstanding symptom. However, the irregularities of flow and even hypomenorrhea are seen not infrequently. Acquired dysmenorrhea has often been considered as one of the symptoms *par excellence* of endometriosis and certainly is of great value in its diagnosis. Rectal pain, especially during the menstrual period, is also frequently a part of the story and results from invading rectovaginal implants. With involvement of the ovaries and with the fixation which is so often characteristic of the disease, dyspareunia is occasionally present. Infertility is commonly associated with endometriosis and oftentimes the pathologic condition present seems inadequate to account for it. It has been estimated that approximately 16 per cent of patients with pelvic endometriosis become pregnant.

The cardinal sign of endometriosis is the presence of shotty nodules in the cul-de-sac and rectovaginal septum; this observation on rectovaginal bimanual examination is almost pathognomonic of the disease. Uterine retrodisplacement, usually with fixation, is a common observation, and adherent adnexal enlargements without evidence of infection are suggestive. Cervical stricture is frequently an associated observation and perhaps is of etiologic importance.

The described symptoms and signs point to the diagnosis of endometriosis in the usual case, and the history and observations in typical instances lead to little confusion in establishing the gynecologic nature of the disease. However, in some of its more unusual manifestations endometriosis is difficult of diagnosis, and in some cases even the pelvic nature of the disease may not be apparent. The picture may be more typical of urinary or intrinsic bowel disease, and occasionally may be such as to create a real problem in the differential diagnosis of an acute condition within the abdomen. Symptoms of ureteral obstruction or invasion of the bladder occur occasionally, and there may be enough involvement of the rectum or rectosigmoid to produce obstruction of the bowel. The similarity to carcinoma may be striking, so that there is difficulty in the differential diagnosis even at the operating table. I have seen several cases in which the decision relative to the propriety of resection of the bowel was difficult to make. If the diagnosis of endometriosis can be established, castration is preferable to resection, since is is usually followed by gradual atrophy of the endometrial tissue with eventual spontaneous recovery.

During the last few years, I have collected 12 cases of special interest in the discussion of endometriosis in general abdominal surgical procedures. The picture in this group was one of acute disease which suggested in many instances the diagnosis of acute appendicitis. This

error in diagnosis was mine in some instances, while in others it was that of the general surgical service. These cases presented a picture of generalized abdominal pain with localization in some patients. Definite peritoneal signs were present, apparently the result of irritation from spillage of old grumous bloody material from within the endometriotic lesions. Leukocytosis and fever were usual, and nausea was reported in most instances.

REPORT OF CASES

The following 4 cases are typical examples of the group under discussion and represent recent admissions.

CASE 1.—E. C., a 43 year old divorcee, entered the hospital at 10 p. m. on January 9, complaining of moderately severe abdominal pain localized in great part to the right lower quadrant of the abdomen. She stated that shortly after noon of the same day she experienced the onset of a generalized abdominal pain and nausea. She had vomited twice during the afternoon and had eaten nothing since breakfast. The pain continued to increase during the afternoon and gradually localized to the right lower quadrant of the abdomen. Constipation or diarrhea was not reported.

On her admission to the hospital, abdominal examination revealed some rigidity of the lower right rectus muscle, some generalized tenderness and decided tenderness to palpation in the right lower abdominal quadrant. There was definite rebound tenderness referred to the right lower abdominal quadrant. The patient's temperature was 99.6 F., and her white blood cell count was 27,200. No record of a preoperative rectal or vaginal examination appeared on the patient's chart. Urinalysis revealed no abnormality. The impression was of acute appendicitis, and the patient was prepared for operation.

The observations at operation included much free fluid in the peritoneal cavity, bilateral chocolate ovarian cysts of orange size and a normal appendix. The fluid was of a turbid grumous nature, resembling old blood, and was observed to be emanating from the left ovarian chocolate cyst. Unquestionably, the preoperative picture here was the result of spillage of material with peritoneal irritation. Although a right rectus incision had been made, a supracervical hysterectomy with bilateral salpingo-oophorectomy was done. The pathologic report was "endometriotic tarry cysts of the ovaries."

CASE 2.—H. V., a 35 year old married woman, entered the hospital during the evening of January 17, complaining of pain in the right lower abdominal quadrant, of three days' duration, with acute exacerbation during the preceding twenty-four hours. She had been nauseated and had vomited several times. Her bowel function was normal. She gave a history of similar, but less severe, attacks during the year prior to admission. A supravaginal hysterectomy, with removal of "cysts" from both ovaries, had been performed elsewhere four years previously.

Abdominal examination revealed tenderness throughout the abdomen, with slight rigidity and definite rebound tenderness. Pelvic examination revealed bilateral adnexal masses, the left orange sized and the right half as large. The patient's temperature was 99.2 F., and her white blood cell count was 13,200. Urinalysis revealed no abnormalities.

Although pelvic examination had revealed the presence of adnexal disease in this patient, she was operated on as a semiemergency the night of her admission to the hospital because it was impossible to rule out a diagnosis of acute appendicitis.

A midline abdominal incision was made, and a small innocent appendix was found. The adnexal enlargements were seen to be bilateral endometriotic chocolate cysts of the ovaries, the smaller one on the right having ruptured. Both tubes and ovaries and the appendix were removed.

CASE 3.—A. K., a 26 year old married woman, entered the hospital at 2 p. m. on March 4, complaining of severe cramping pain in the lower part of her abdomen, especially on the right side. She stated that the pain had begun that morning and had become increasingly severe. She had had no nausea until the time of her admission. She had had a normal bowel movement during the morning. She had just finished a normal menstrual period, which had begun on time. Abominal examination revealed decided tenderness in the lower part of the abdomen, especially the right lower quadrant, where definite rigidity was elicited. Rectovaginal examination revealed tenderness high on the right side. No other observations were recorded. The patient's temperature was 100.4 F., and her white blood cell count was 23,600. Urinalysis revealed no abnormalities. The preoperative impression was of acute appendicitis.

A right rectus incision was made and free dark thick chocolate fluid was observed in the peritoneal cavity. Considerable endometriosis was encountered throughout the pelvis, with many adhesions and nodulations. The source of the chocolate fluid was a ruptured endometriotic cyst of the left ovary, measuring approximately 6 cm. in diameter. The left chocolate cyst and the appendix were removed. The latter was normal.

CASE 4.—E. O., a 23 year old virginal woman, entered the hospital on the evening of January 22, with intense abdominal pain which, although generalized, was particularly severe in the right lower abdominal quadrant. Her discomfort had begun the night before, when she had been awakened because of a "stomachache." The pain had become increasingly severer and the patient had vomited three times. She was nauseated on her entrance to the hospital. She had had a normal bowel movement during the day.

The patient was in severe pain when first seen in the hospital. Her knees were drawn up and her abdomen was extremely tender to palpation. Rigidity was apparent, perhaps most so in the right lower abdominal quadrant. Bowel sounds were active; the urine was normal, and the white blood cell count was 22,000. The patient's temperature was 101.4 F.

The preoperative impression on the general surgical service was of acute appendicitis, but prior to operation a rectal examination was made. A nodular "mass" in the region of the cul-de-sac was encountered and gynecologic consultation called. Bimanual rectovaginal examination revealed nodules in the cul-de-sac and rectovaginal septum. An impression of a right adnexal mass was obtained, but the extreme abdominal tenderness and rigidity precluded any accurate evaluation of the pelvis. Following these observations, a history of acquired dysmenorrhea, menorrhagia and intense rectal distress on defecation during a menstrual period was elicited. The patient had just begun to menstruate and reported that on previous occasions she had had lesser episodes of abdominal pain concomitant with the onset of menses.

With this additional history and the observations on pelvic examination, a diagnosis of pelvic endometriosis was made. A conservative course was followed, and with watchful expectancy the acute condition subsided. Three weeks later pelvic examination revealed the same observations as reported previously, with the additional impression of a fixed orange-sized right ovarian cyst. The diagnosis of

endometriosis seemed confirmed, and a month following the acute episode an abdominal section was performed through a midline incision. The right adnexal mass proved to be an endometriotic tarry cyst, which had apparently ruptured during the previous episode. Serosanguineous fluid was seen throughout the pelvis and lower part of the abdomen, with scattered areas of organizing old blood clot. Many newly formed filmy adhesions were encountered. A great many nodules were seen in the cul-de-sac and uterosacral regions involving the rectosigmoid. The left tube and ovary were normal. A conservative operation was performed with removal of the endometriotic tissue, including the right tube and ovary.

SUMMARY AND CONCLUSIONS

The purpose of this presentation is not to discuss or recommend any of the reported procedures as the procedure of choice in the treatment of endometriosis. Nowhere in gynecologic surgery are there more opinions as to the proper disposition of pathologic processes encountered, and the treatment of each patient represents an individual problem, the answer to which is dependent on many factors. Moreover, it is not my wish to minimize the importance of appendicitis in the differential diagnosis of acute abdominal conditions. Surely, it is far better to operate on a patient with endometriosis which has been misdiagnosed than to fail to recognize acute appendicitis when it is present. However, the optimum time for intervention, the type of incision to be made and an accurate explanation of the situation to the patient, with reference to what may have to be done, all make a preoperative diagnosis necessary. The lesson I have learned from such cases as described is that endometriosis should be kept in mind. It has assumed great importance in the differential diagnostic problems encountered in gynecologic practice and may well be confused with many abdominal and pelvic conditions, occasionally even with those of an acute nature. It is hardly necessary to point out the important need for a carefully taken gynecologic history and bimanual rectovaginal pelvic examination for all women suspected of having pelvic or lower abdominal pathologic conditions and those suspected of having appendicitis.

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